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T H E
DESCRIPTION and USE
OF THE
Universal Trigonometrical OCTANT,

Invented and applied to HADLEY'S QUADRANT

By GEORGE ADAMS

Mathematical Instrument-Maker to His Majesty's
Office of Ordnance, at *Tysbe Brabe's* Head in
Fleet-Street, LONDON.

THIS Instrument gives the Latitude of the Place by immediate Inspection, without Calculation or Recourse to Tables of the *Sun's Declination*; and this with the utmost Accuracy in all the Variety of Cases that can be supposed to happen, as well for the Leap Years as for either of the three Years after.

It is also adapted to solve by a short and exact Method every Day's Reckoning, whether it be a TRAVERSE or otherwise, upon the Principles of PLAIN, MIDDLE-LATITUDE or MERCATORS SAILING, without consulting the common Tables of the *Difference of Latitude and Departures*, or of *Meridinal Parts*; and by it a *Journal* may also be kept in an easy accurate and expeditious Manner.

L I K E W I S E

By it the Sun's AMPLITUDE and AZIMUTH may be readily obtained, without the Assistance of the Tables of *Logarithms*; and the most useful *Problems* in PLAIN and SPHERICAL TRIGONOMETRY may be solved thereby,

L O N D O N :

Printed for G. ADAMS, as above, and given only with
the *Instrument*. 1753.

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By GEORGE ADAMS

Office of Ordnance & Survey, 1795



BRITANNICVM

It is also adapted to solve by a short and exact Method every Day's Reckoning, whether it be a TRAVELLER or otherwise, upon the Principles of PLAIN, MATHESIS, LATITUDE or MERCATORS SAILING, without consulting the common Tables of the Difference of Latitude and Distance, or of Mercators Parts; and by it a Journal may also be kept in an easy accurate and expeditious Manner.

J. I. K. E. W. I. B.

It is the Sun's Attitude and Azimuth may be readily obtained without the Assistance of the Table of Logarithms; and the most useful Problems in Plane and Spherical TRIGONOMETRY may be solved thereby.

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Printed for C. Adams, as above, and given only with
the instrument. 1553.

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DESCRIPTION and USE

OF

The New Universal Octant.

Contrived and Made

By GEORGE ADAMS,

MATHEMATICAL INSTRUMENT-MAKER to

his Majesty's Office of Ordnance,

**At Tycho Brahe's Head, the Corner of
Racquet-Court, in Fleet-Street, London;**

and applied to HADLEY'S QUADRANT.

THIS valuable Improvement is perform'd
by giving a circular sliding Motion
Q R. to the Degrees of the Octant, Fig. 3,
and above them, in two concentric Arches of
Circles, the Days of the Month in a common
Year, over which, in a third, is the Sun's De-
clination. On each Side the Equator marked
Æ, which may be read off by Inspection to a
single Minute (on applying the Index, or Tooth

A

I to

I to the Day of the Month) as well for the Leap-Years as for the first, second and third Years after.

Before I shew the Use of this new Invention it will be necessary to explain the Nature of *Hadley's Quadrant*, and the Manner of taking an Observation by it in the common Way.

The Divisions on the sliding Arch of this Instrument are the same with those usually put on a *Hadley's Quadrant*, and differ only in the numbering, the former being numbered for the Altitude, and this for the Zenith Distance, and are accurately divided into Ninety equal Parts or Degrees, which are again subdivided into 20 Min. The whole Degrees are distinguished by Lines drawn through three concentric Circles, and the other Subdivisions of 20 Min. each, are pointed out by Lines drawn through the two outward concentric Circles; and these last Subdivisions are again subdivided into Minutes, by Means of a Nonius Division upon the Index, which is moveable about the Center, and marks the Divisions graduated on the Arch, over the Center of the Instrument; but on that of the Index is fixed a Glass Mirrour D at right Angles to the Plane thereof. This Glass alters its Direction as the Index slides along the Arch, and reflects the Image of the Sun or Star to either of the Horizon-Glasses; that is, to the South Horizon Glass G, for the fore Observation, and to the North Horizon Glass H, for the backward Observation.

The

The Glas G hath that Part quicksilvered which is next the Plane of the Octant, the upper Part being left transparent on purpose, to see the Horizon through it. This Glas returns a second Image of the Sun or Star to the Eye, placed at the South Vane L, in forward Observations.

The Glas H receives the second Image from the Index Glas D, and reflects it to the Eye placed at the North Vane M, in backward Observations. This Glas has a narrow transparent opening thro' which the Horizon is to be viewed.

Each of these Glasses G and H, have a circular Motion parallel to the Plane of the Instrument, by means of two Leavers placed on the backside of the Quadrant; and by means of two Screws which pass through the Foot of each Glas, may be set perpendicular to the same Plane, if they should by any Accident, &c. be altered from that Position.

The Leavers are seen at g g, Fig. 2, which represents the backside of the Octant.

There are two red Glasses at K, fixed in Brass Frames, being one of a lighter, the other of a darker Colour. Their Use is to prevent the Sun's bright Rays from offending the Observer's Eye; these move on one Center, and may be used either separate or together, according to the Brightness or Faintness of the Sun.

These coloured Glasses, when used in the fore Observation, are to be put into a Hole at

(4)
For the backward Observation
the North Vane L. for the fore Observation
the South Vane I. for the fore Observation
the Hole is to direct the Sight, one at the
Middle of the Quicksilver'd Edge, the other
at the Middle of the transparent Part of the
South Horizon Glass G.

The North Vane M. for the back Observa-
tion, hath but one Hole placed at the Middle
of the transparent Part of the Glass H.

There is great Curiosity in the Glasses; for
they ought to be most perfectly flat, and of an
equal Thickness, that thereby both their Sur-
faces may be perfectly parallel to each other, in
order to have but one reflected Image, which is
the Reason that common looking Glasses will
show double. The dark Glasses ought also to be

The Professor may easily know whether
the Glasses be good by taking Notice of any
bright Object, as the Sun, whether the Edges
do appear perfectly sharp, distinct, and in one
which can never be unless the Planes of the
Glasses are truly parallel, and they are best
used when the Index is near 90 Degrees, which
will show the Error most.

To adjust the Glasses.

For the fore Observation, set the Index to
0 Degrees, by bringing it close to the
Point, which will stop it at that very Point;
but

(5)

but first you must observe to bring the Line marked AE upon the sliding Arch exactly to the middle of the Nonius ST , Fig. 3 and 3; and holding the Instrument upright, look thro' the lower Hole in the South Vane L , and through the transparent Part of the South Horizon Glass G , and observe whether the Edge of the Sea seen in the quicksilvered Part joins in the same streight Line with the same Edge seen through the unquicksilvered Part; if not, bring them into one Line by the Help of the Leaver under the Glass G on the Back of the Instrument.

For the back Observation, bring the Edge of the Sea, seen by Reflection, to coincide with the Edge of the Sea seen through the transparent Slit of the Glass H , by Help of the Leaver g , Fig. 2, on the Backside of the Instrument, the Index being first set as much beyond ninety Degrees, as double the Angle of the Dip* of the visible Horizon;—because, if you are much above the Surface of the Sea, you are not in the same streight Line with the two opposite Parts of the Horizon. *Example*: Suppose the Observer to be elevated above the Surface of the Water 12 Feet, the Dip of the visible Horizon will be 4 Minutes forwards; and as much backwards; therefore the Index must be set off eight Minutes before the Beginning of Degrees.

* See the Table for the Angle of the Dip of the Sea above the visible Horizon in Page .

•• The Edge of the Sea seen from behind by Reflection will be inverted, *i. e.* the Water will appear above, and Sky below; and, if the two Edges of the Sea cross each other, the Instrument is not held upright.

*To observe the Zenith Distance of the Sun
or Stars.*

The sliding Arch being first set, so that 70 Degrees, or that Degree marked Æ upon the sliding Arch, exactly correspond with the Middle of the Nonius ST , see Fig. 3; then hold the Octant, as upright as may be, with the Arch downwards, your Face to the Sun, and placing your Eye to the South Vane L , for the forward Observation, direct your Sight through the transparent Part of the Glass G , to that Part of the Horizon which lies directly under the Sun, and by moving the Index forward, bring the Image of the Sun to appear as tho' it really lay upon the Edge of the Sea; and the Degrees and Minutes pointed out by the Index is the Zenith Distance. In this Case the Image of the Sun appears in the same Position as when seen by the naked Eye, that is, It is not inverted.

If the Reflection be too bright for the Eye, turn up one or both of the coloured Glasses as Occasion requires.

When the Sun is made to appear upon the Horizon, if you lean the Instrument first to the right

right and then to the left Hand, it will seem to describe an Arch, the lowest Part of which must be set to the Horizon, and then the Instrument is perfectly upright.

For the Back Observation hold the *Oblant*, as before, as upright as possible, with your Back towards the Sun; and placing your Eye to the North Vane M, look through the transparent Part of the Glass at the Horizon, and at the same Time slide the Index till the Image of the Sun joins the Edge of the Sea.

In order to know when the Instrument is held upright, keep it and your Arm steady and turn yourself sideways, (as it were upon your Heel) to the right and left, and you will see the Image of the Sun glide along the Horizon, if the Instrument be in a vertical Position, and if not, the Sun will describe a Line which crosses the Edge of the Sea.

To observe by a Star Forwards; Set the Index to the Beginning of Degrees, and look up directly at it, by which Means it will appear in its own Place as well by Reflection as it does to the naked Eye.—Then slide the Index, and the Star will descend till it touches the Horizon, by which Method you'll neither lose Sight of it, nor mistake it for any other Star.

When the Horizon is bright, and the Star faint, it will be more convenient to use the Back Observation; therefore look directly at the Star, and bring the Edge of the Sea to touch the Star by Reflection, and the Index will shew its Zenith-Distance.

To find the Latitude at Sea.

An Observation must be made, and frequently repeated, before the Sun comes to the Meridian, in order to obtain his greatest Height, or Zenith Distance, by which, and the Declination of the Sun taken out of the Tables for that Purpose, the *Latitude* may be readily found, according to the common Rules delivered in every Treatise of Navigation.

I shall now proceed to shew how to find the Latitude of the Place, by immediate Inspection or by the new Contrivance applied to this Instrument.

The sliding Arch, before described, is divided into 90 Degrees, and these again subdivided into 20 Min. each; over this, in two Sets of concentric Circles, are the Months in two half Years; the uppermost contains the Months from the Winter Solstice to the Summer Solstice, beginning from the 22d of *December*, and proceeding from the left Hand towards the right, thro' *January, February, March, &c.* to the 21st of *June*; the lowermost Circle of the Months beginning at the 22d of *June*, and going on thro' *July, August, September, &c.* to the 21st of *December*, from the right Hand, towards the left. See Fig. 3 and 5. The tenth Day of each Month is numbered 10, 20, 30, &c. every fifth Day is distinguished by a Diamond, and each respective Day is expressed by a shorter Division between two concentric Arches. Each Day is divided into
Half

Half by a small Dash, the Use of which will be explained hereafter.

Above the Circles of Months, is divided 47 Degrees for the North and South Declination, beginning in the Middle of the Arch marked Æ , and numbered each way from thence at every Degree, 1, 2, 3, 4, 5, &c. to 23. These Degrees are subdivided in 6 Parts, containing 10 Minutes each, which are again subdivided by the Nonius O into single Minutes, as shall be explained in the Description of the *Nonius Divisions*.

Here it will be proper to lay down Three short Rules for finding the Latitude, which, being once understood, will render the Practice of this New Improvement perfectly easy.

RULES for finding the LATITUDE of a Place.

I.

Add the Sun's Declination for the Time of Observation, if it be on the same Side of the Equator with the Zenith, to the Zenith Distance; and

II.

Subtract it, if on the other Side; then in the first the Sum, in the second the Remainder, will be the Latitude.

III.

It may happen between the Tropics, that the Sun and Zenith Point are both on the same

Side of the Equator, and the Declination greater than the Zenith Distance; in which Case it must be Subtracted therefrom to obtain the Latitude.

Demonstration.

Let Æ Q , Fig. 4 represent the Equator, Z the Zenith, H O the Horizon, Æ Z will be the Latitude of the Place.

1st, Suppose the Sun at B , then the Arch B Z will be his Zenith Distance, and Æ B the Sun's Declination.

Hence, as in the *first* Case, it is evident that, if the Sun's Declination, Æ B , be added to B Z , his Distance from the Zenith, their Sum Æ Z will be the Latitude.

2^{dly}, If the Sun be on the contrary Side of the Equator at C , his Declination C Æ , being subtracted from C Z , his Distance from the Zenith, will leave Æ Z , the Latitude, as in the *IId* Case.

3^{dly}, Suppose the Sun at D (where, as in the *IId* Case, the Declination Æ D is greater than the Zenith Distance Z D , and yet both on the same Side of the Equator) the Zenith Distance Z D must be subtracted from Æ D , the Sun's Declination, to give the Latitude Æ Z .

Hence, from a through Knowledge of the Three foregoing Rules, the Latitude may be had by the Quadrant without any Calculation.

How

*How to find the Latitude without Calculation by
the Universal Octant.*

First set the fiducial Line of the Tooth, I, Fig. 3, 5, and 7, in the Middle of the Index, to the Day of the Month, and the Nonius Q, above it, will give you the Degrees and Minutes of the Sun's Declination for that Day at Noon.

N. B. If it falls to the right Hand of the middle Line marked $\mathcal{A}$, the Declination is North, if to the left Hand it is South.

The Sun's Declination being thus obtained, it will be easy to know whether the Zenith Point be on the same or on the other Side of the Equator, and whether it be between the Sun and the elevated Pole, or between him and the Equator.

If then, as in the *first* Case, they are both on the same Side, slide the Arch Q R towards the left Hand to increase the Zenith Distance by the exact Quantity of the Declination.

In the *second* Case, slide the Arch Q R towards the right Hand to lessen the Zenith Distance by the *afore said* Quantity.

The sliding Arch being thus set against the Nonius S T, to the same Declination found as above, make your Observation as usual, by bringing the Sun's lower Limb to touch the Horizon, and the lower Nonius V V will give you the Latitude of the Place upon the sliding Arch Q R. Fig. 3, 5, and 7.

In

In the *third* Case, if the Zenith should happen to be between the Sun and the Equator, first find the Declination, as before directed, which chalk down, or remember it, then make your Observation as before, by bringing the Sun to appear in the Horizon; and when you find the Sun is up (as the Seamen term it) fix your Index at that Place by a slender touch of the Screw X, *Fig. 2.*) which is on the Back-Side thereof; and then move the sliding Arch, so that the Nonius V V. *Fig. 3* and 5, may cut the Sun's Declination for that Day, counted from Q the Beginning of the sliding Arch, and you will have the Latitude of the Place pointed out by the Nonius S T, *Fig. 3, 5, and 6,* to be counted amongst the smaller Figures, that begin on the sliding Arch, at the Equinoct $\mathcal{A}$, as in *Fig. 6,* and which, in the *first* and *second* Case, were used for setting the Arch to the Sun's Declination, are now used to give the Latitude of the Place. An Example in each Case will make all plain.

But first it will be more convenient to explain the Nature of a Nonius Division, and the separate Nonius's on this Instrument.

The Description and Use of the Nonius Divisions.

For the right understanding the Reason of these Subdivisions, it will be necessary to premise, That if a right Line A B, *Fig. 1,* be divided into any Number of equal Parts, A c, c d, d e, e B, and an equal Line, F G, be divided into

into other equal Parts, one more in Number than the Parts of the Line A B.

I say that F h, h i, i k, k l, l G, will fall short of A c, A d, A e, A B, respectively by 1, 2, 3, 4 Parts of A c; for let the Lines A B and F G be coincident at both Ends, then by the 15th of the V. of Euclid, as any multiplies of two Quantities A c, and F h, have the same Proportion as the Quantities themselves, it will be as, $A c : F h :: A d : F i :: A e : F k :: A B : \text{or } F G : F l$. and disjointly as $A c : c h :: A d : d i :: A e : e k :: A B \text{ or } F G : B l \text{ or } G l$: the Consequents c h, d i, e k, B l, are therefore in the same Arithmetical Progreſſion, as the Antecedents A c, A d, A e, A B, and the first of the Consequents c h, is the same Part of its Antecedent A c, as the last Consequent B l is of the last Antecedent A B; or as F h is of F G, the Number of Parts in A B and F l, being equal by the first Supposition. It is also manifest that any two coincident Arches of a Circle will have the same Property.

The Description of the several Nonius Divisions, applied to the Arch of the Universal Octant.

I have substituted a Part of the Quadrantal Arch in Fig. 7. which, together with as much of the Index as contains the several Nonius's, is drawn of its real Size, that the Reader might the more readily understand the Nature of these admirable Subdivisions.

The

The Nonius VV, *Fig. 3, 5, 7*, which is near the End of the Index, moves against the Divisions of the sliding Arch, whose Degrees are divided into 3 equal Parts, containing 20 Minutes each; therefore, to subdivide those Divisions in single Minutes, it is necessary, that nineteen of these, or $6^{\circ} 20'$. be taken for the Length of the Nonius VV, *Fig. 7*, and that Length VV, divided into 20 equal Parts; then will each Division in the Line VV be smaller than the third Part of a Degree, or 20 Minutes, by the twentieth Part of 20 Minutes, that is one Minute.

The Middle Line of this Nonius VV, *Fig. 7*, stands at 51 Degrees 20 Minutes, and somewhat more; therefore, in order to determine how many Minutes more, pass your Eye along them from the middle Line towards the right Hand, and you will find that the Eighth Division of the Nonius exactly corresponds with the Eighth Subdivision of the Degrees, from $51^{\circ} 20'$ which shews that the Angle of the Index or Zenith Distance is 8 Minutes more than $51^{\circ} 20'$, which is $51^{\circ} 28'$.

The Nonius S T, which is to set the sliding Arch to the Declination, is exactly the same as that just now described, and therefore needs no farther Explanation; but reckoning from the Equinox *E*, it stands at five Degrees one Minute of the sliding Arch,

The Degrees on the upper Arch YZ, *Fig. 7*, are divided into six equal Parts, or 20 Minutes, therefore 9 of them were taken for the Length
of

of the Nonius O, which being divided into 10 equal Parts, each Division of the said Nonius will be smaller than the sixth Part of a Degree or 10 Minutes, by the tenth Part of 10 Minutes, that is, one Minute.

The middle Line of this Nonius O, points to $5^{\circ} 40'$ and something more; therefore to know how much more, look amongst the Divisions of the Nonius, and you'll find that the two Extremes thereof, which are 5 Minutes, will coincide with the 5th Subdivision of the Degrees each way from $50^{\circ} 40'$, which shews that the Nonius O, points to $5^{\circ} 45'$ Minutes.

The Nonius R is exactly the same as that last mentioned, and points to $16^{\circ} 45'$.

The Line e, on the Tooth I, Fig. 7, is to be set to the Day of the Month, and then the Nonius O will give the Sun's Declination.

The Divisions on the Nonius O, the Nonius R, and the Nonius S T, are each of them numbered backwards and forwards.

Therefore observe, when the Degrees against which they stand, have their Numbers increasing towards the right Hand, read off the Numbers of the Nonius increasing to the right Hand also; but when the Numbers of the Degrees increase towards the left Hand, read off the Numbers of their respective Nonius increasing to the left Hand also.

Here

Here the Reader is desired to take particular Notice, once for all, that the Numbers on the Nonius's, are all to be read off increasing the same way as the Numbers do upon those Degrees, &c. that they are intended to subdivide.

When it happens that no one Stroke upon the Arch is directly opposite to a Stroke upon the Nonius; then look for that single Part upon the Limb which is so opposed to a single Part upon the Nonius, as to exceed it at both Ends equally; then you may allow 30 Seconds more.

This way of subdividing by a Nonius, is preferable to the common method by Diagonals; because they cannot be drawn so exactly as the Lines upon the Nonius, and also because their Intersections with the Index or fiducial Edge, cannot, by Reason of their great Obliquity to each other, be determined so exactly by the Eye, as the coincidence of two Strokes in the Nonius and Arch, which stand directly opposite to one another.

I shall now proceed to shew how to find the Latitude of the Place.

EXAMPLE I. RULE I.

The Sun's Declination and Zenith Distance; both on the same Side of the Equator, *adds*; therefore

therefore set the Line on the Tooth I to the Day of the Month, suppose the 2d of *April*; and the Nonius O, *Fig. 2*, will shew the Sun's Declination to be 5 Degrees and 7 Minutes North.

Then slide the Arch Q R from B towards C, that is, towards the left Hand, until the Nonius S T points to 5 Degrees, 07 Minutes, which will increase the Zenith Distance by the aforesaid Quantity; there letting the Arch remain in that Situation, make your Observation by bringing the Sun's Limb to cut the Horizon; and then the lowermost Nonius upon the Index V V, will point out the Latitude of the Place.

EXAMPLE II. RULE II.

The Sun's Declination on one Side the Equator, and Zenith on the other, *Subtracts*.

Set the Tooth I on the Index to the Day of the Month, suppose the 4th of *May*, and the Nonius O will point to the Sun's Declination, 16 Degrees, 06 Minutes North, at the same Time your Zenith being between the South Pole and the Equator, which by the second Rule, requires the sliding Arch to be set so as to lessen the Zenith Distance; therefore move it towards the right Hand, until the Nonius S T points at 16 Degrees 06 Minutes, the Sun's Declination for that Day, where, letting the sliding Arch remain, make your Observation

by bringing the Sun's Limb to the Horizon, and then the Nonius VV, will shew the Latitude of the Place.

EXAMPLE III. CASE III.

The Zenith between the Sun and the Equator, *Subtracts*.

Therefore set the Tooth I, to the Day of the Month, suppose *June* the first, and the Nonius O, will mark out the Declination of the Sun for that Day, $22^{\circ} 09'$ *North*. And as the Zenith is supposed to be between the Sun and the Equator, either remember the Declination found as above, or chalk it down.

Then observe, as usual, by bringing the Sun and Horizon to Coincide, and when you find the Sun is up, fix the Index, by the Screw x, *Fig. 2.* on the Back thereof. This being done, move the sliding Arch, so that the Nonius V V, *Fig. 3* and *5*, may cut the Declination $22^{\circ} 09'$, counted from Q, the beginning of the said sliding Arch, and you will find the Latitude of the Place pointed out by the Nonius ST, *Fig. 3, 5, 6*, to be counted amongst the smaller Figures, that begin at the Equinoctial, marked *Æ*, as in *Fig. 6*, (amongst which, in the two first Cases, the Declination was counted; but in this *third* and *last* Case, will give the Latitude of the Place.)

These are all the possible Cases that can be supposed to happen, with respect to observing the

the Latitude of the Place only. We must allow for the Sun's Semidiameter, which is 16 Minutes; and if the lower Limb be used, it must be Subtracted from the observed Latitude, if the upper added thereto, and you will have the true Latitude of the Place.

A Caution to be Observed.

The Dip of the Horizon is likewise to be considered, if you would have the Latitude nicely determined; and as the Height of the Observer, above the Water, will be nearly the same, in the same Ship, during any particular Voyage, provided he always stands on the same Part of the Ship to observe.

Suppose him then to be 18 Feet above the Surface of the Sea, which is 5 Minutes to be added to the Latitude found by the Quadrant, and the Sun's Semidiameter, being 16 Minutes to be Subtracted therefrom, (if the Sun's lower Limb be used, which is much better to use than the upper Limb, because the Coincidence of it with the Horizon will be better determined) their Difference, 11 Minutes, will be a constant Number for that Voyage, which I would advise to write down, in Black-Lead, on the inside Edge of the Arch, where it will be always ready to be Subducted from the observed Latitude, and may be done, in the Mind, very readily. See the Table of the Dip of the Horizon, in Page 25.

By

By this Time, I suppose the Reader to have attained a perfect Knowledge of the Nature of this new Construction, and that he can readily manage the sliding Arch, in each of the three foregoing Cases; and also read of the Minutes by the Nonius Divisions. I shall next shew him how

To find the Sun's Declination, for the first, second, and third Year after Leap Year, as well as for the Leap Year itself.

The Divisions for each respective Day of the Month, are laid down for the Noon of each Day; and that the Declination of the Sun may be had exactly to a Minute, you must consider what Year it is from Leap Year. For if it be the first after Leap Year, the Divisions themselves are the Respective Days of the Month to which the fiducial Edge I, must be laid and then the Nonius O, will give the true Declination.

EXAMPLE.

This Year, 1753, being the first after Leap Year, what is the Sun's Declination for the 25th of January?

Set the fiducial Line of the Tooth I, to the 25th of January, and the Nonius will stand at 18 Degrees 50 Minutes, S. Declination.

Again set the Tooth I, to the 12th Day of July, and

and the Nonius O, will give you $21^{\circ} 58'$ the Sun's Declination N, for that Day.

If it be the second Year after Leap Year, the fiducial Line I, must not be set exactly upon the Divisions, but one Quarter of a Division backwards, which is a Quarter of a Day, and then the Nonius O, will give the Sun's Declination, as before.

EXAMPLE II.

Let the Sun's Declination for the 20th Day of *February*, 1754, be required, it being the second Year after Leap Year.

Set the fiducial Line I, one Quarter of a Day backwards from the Division, answering to the 20th of *Feb.* and the Nonius will point to $10^{\circ} 50'$ S. *Dec.*

Again, for the 15th Day of *April*, 1754. set the fiducial Line I, it being the second Year after Leap Year, a Quarter of a Day backward, from the Division answering to the 15th Day of *April*; and the Nonius O, will point out $9^{\circ} 50'$, N. *Dec.*

EXAMPLE III.

I would know the Sun's Declination for the 10th of *August*, 1755.

This being the third Year after Leap Year, I set the fiducial Edge of the Tooth I, half a Day backward. from the Stroke answering to the
the

the 10th of *August*, and the Nonius O. will then point out $15^{\circ} 39'$, N. Declination:

Also, on the 13th of *October*, 1755 being the 3d Year after Leap Year; I set the fiducial Edge of the Tooth I, half a Day backward, from the 13th; and the Nonius O, will shew $7^{\circ} 44'$, for the Sun's Declination, S. on that Day.

If it be Leap Year, then the fiducial Edge I, must be set three Quarters of a Day backwards, from the 22d Day of *December*, to the 28th of *February*.

EXAMPLE.

The Sun's Declination is required on the 25th Day of *January*, 1756, it being Leap Year, and before the 28th Day of *February*; therefore I set the fiducial Edge of the Tooth I, 3 Quarters of a Day backward from the Division answering to the 25th; and the Nonius O, will give $19^{\circ} 01'$ S. Dec.

And for the 28th of *February*, the Tooth O, being set 3 Quarters of a Day back, will give $8^{\circ} 03'$, South Declination. For the 29th, 3 Quarters of a Day backwards, from the first of *March*, is, $7^{\circ} 40'$, S. Declination for that Day, but for the first of *March* itself, the fiducial Edge I, must be set one Quarter of a Day forward from the Division, representing the first of *March*, and the Nonius O, will give $7^{\circ} 17'$, S. Dec. for that Day.

There-

Therefore from the the first of *March*, in Leap Year, to the 21st Day of *December*, set the fiducial Edge I, one Quarter of a Day forward, and the Nonius O, will point out the Sun's Declination.

EXAMPLE.

For the 10th of *March*, 1756, it being Leap Year, and past the Leap Day, therefore I set the Tooth I, one Quarter of a Day forward from the 10th, and the Nonius O, will give $3^{\circ} 48'$, S. Declination.

Again, on the 28th of *April*, I set the Tooth I, a Quarter of a Day forward, and find, by the Nonius O, the Sun's Declination to be $14^{\circ} 23'$.

From what has been already said concerning the Declination, the Reader may observe, it is all contained in the following Lines.

If the Declination is required for the first Year after Leap Year, the Division for the Day of the Month is right.

If the second Year after Leap Year, then a Quarter of a Day backward, is the Day of the Month for all that Year.

If the third Year after Leap Year, half a Day backward, is the Day of the Month for the whole Year.

If Leap Year, 3 Quarters of a Day back, is the Day of the Month, until the 29th of *Feb.* which is the Leap Day, and is actually expressed $\frac{1}{4}$ of a Day backward from the 1st of

D

March,

March, and the first of *March* itself, is $\frac{1}{4}$ of a Day forward; and so also, from thence to the 22d Day of *December*, in any Leap Year, the Day of the Month is $\frac{1}{4}$ of a Day forward, from the Day expressed upon the Arch.

That the Latitude of a Place, taken by this Instrument, may be as correct as possible, it must be observed, that when the Eye of the Observer, is above the Surface of the Sea, the Plane, passing through the Center of his Eye parallel to the Horizon, will be above the real Horizon, so that the Sun's, Zenith Distance, or Latitude, taken by this Quadrant, will, by that Means, be as much too little, as the Plane of that apparent Horizon is below that of the real one; and therefore, that Difference being estimated, must be added to the observed Latitude, in order to find the true Latitude; and as the Height of the Observer's Eye, is more or less from the Surface of the Sea, I have inserted a Table of Correction for that Purpose.

Since from the Principles of Optics, Rays of Light, in passing from a Rarer into a Denser Medium, are refracted towards the Perpendicular; therefore the Rays that proceed from the Sun, must, by the interposing Atmosphere, be refracted towards the Perpendicular, before they can reach the Surface of the Earth; consequently the observed Latitude will be greater than the real Latitude.

The

((25.))

The Refraction being different in different Altitudes, I have inserted Mr. FLAMSTEAD's Table thereof.

A TABLE shewing the Depressi^{on} or Dip of the visible Horizon, below the true Horizontal Plane; according to the several Heights therein mentioned of the Observer's Eye above the Surface of the Sea, to be added to the Latitude found by the Quadrant.

The Eye above the Surface of the Sea, in Feet.	Visible Horizon depress'd in Minutes.
1	1
3	2
7	3
12	4
18	5
27	6
40	7

Note. For the Use of the Table of the Dip of the Sea, and of Refraction. See a Caution to be observed in Page 19.

88	0	88	0	1	08	08	7	0
88	0	88	0	1	08	28	0	7
88	0	42	08	1	18	48	8	8
88	0	88	0	1	88	50	2	0
88	0	00	0	1	88	88	4	0
88	0	88	0	1	48	00	4	0
88	0	07	0	1	88	24	8	0
88	0	27	0	1	88	88	8	0
88	0	08	0	1	88	81	8	0
88	0	88	0	1	88	88	8	0
88	0	00	0	1	88	88	8	0
88	0	88	0	1	88	88	8	0

D 2

Mr.

*Mr. FLAMSTEAD'S TABLE of Refraction,
to be Subtracted from the Zenith-Distance, or
Latitude, found by the Instrument.*

Deg. Appt. Alt.	Refract.		Deg. Appt. Alt.	Refract.		Deg. Appt. Alt.	Refract.	
	0	00	18	2	29	41	0	56
0	33	00	19	2	21	42	0	54
$\frac{1}{2}$	26	38	20	2	14	43	0	52
1	23	22	21	2	07	44	0	50
$1\frac{1}{2}$	20	17	22	2	01	45	0	48
2	17	26	23	1	55	46	0	46
$2\frac{1}{2}$	15	15	24	1	50	47	0	45
3	13	23	25	1	45	48	0	44
$3\frac{1}{2}$	11	53	26	1	40	49	0	42
4	10	39	27	1	36	50	0	40
$4\frac{1}{2}$	9	38	28	1	31	51	0	39
5	8	48	29	1	27	52	0	38
6	7	26	30	1	23	53	0	37
7	6	25	31	1	20	54	0	36
8	5	37	32	1	17	55	0	34
9	5	02	33	1	14	60	0	29
10	4	33	34	1	11	65	0	24
11	4	06	35	1	09	70	0	19
12	3	45	36	1	07	75	0	14
13	3	29	37	1	05	80	0	09
14	3	13	38	1	02	85	0	04
15	3	00	39	1	00	90	0	00
16	2	48	40	0	58			
17	2	38						

As the Accuracy of the Observation will, in a great Measure, depend on the two Horizon Glasses, G and H, being truly adjusted to that fixed on the Index, when the Instrument is held in a vertical Position: it will be requisite that the Artist be very careful in performing it, and particularly observe, that during the Operation, the Index continue at 90 Degrees, according to the Directions given in *Page 5* and *6*: And as the Trouble of doing this is but trifling, the Artist would do well to practice it often, because, 'till the Wood is well settled, it will be apt to cast or warp, and consequently, cause an Error in the Observation, which, by this Means, will be prevented; and indeed, the Convenience of altering the Position of these Glasses, is very great, for thereby, the Complaints against other Instruments, of being Northerly or Southerly, that is, of giving the Latitude too great or too little, may be easily prevented.

In accurate Observations Care must be taken to keep the Line, in which the Object is seen, parallel to the Plane of the Instrument; which will be best performed, if you look thro' the upper Hole of the Sight Vane L, by taking the Observation near the Middle of the unquick-silvered Part of the Glass; but if the under Hole be used, the Image of the Object should nearly coincide with the Edge of the Quick-silver; then swing your Body to and fro, and
move

move the Index 'till the reflex Image just brush the Horizon in the lowest Part of its Swing.

These particulars, carefully attended to, will greatly contribute to the Accuracy of the Observation, and render the Use of this admirable Instrument familiar and easy.

N. B. There is a moveable Sight Z, added to the South Vane L, *Fig. 3* and 5, that may be put on or taken off at Pleasure, which will be of great Service when the Sun is bright, and much elevated, and will give the Observer an Opportunity to be more Accurate in his Observation.

THE

THE
U S E
OF THE
Universal Trigonometrical OCTANT,

Invented and applied to HADLEY'S QUADRANT

By GEORGE ADAMS,

Mathematical Instrument-Maker to His Majesty's
Office of Ordnance, at *Tycho Brahe's* Head the
Corner of *Racquet-Court, Fleet-Street*, LONDON.

Shewing how to solve every Days reckoning by a
Traverse, or otherwise upon the principals of
Plain Middle Latitude and *Mercator* SAILING,
without consulting the Tables of Difference of
Latitude and Departure, or of Meridional Parts.

Also how to find the Sun's Amplitude and Azi-
muth without the Assistance of the Tables of
Logarithms, &c.

AMONGST the Variety of Inventions, to
shorten the Labour of Calculation, in
the most useful Parts of Navigation, no Instru-
ment has hitherto appeared which can solve all
the Cases in Plain, Parallel, Middle Latitude,
and Mercators Sailing, &c. in so plain and easy,
as well as in so short and exact a Manner, as
by the present valuable Improvement, applied
to

to HADLEY'S Quadrant; altho' it may be made alone, or applied to any Octant or Quadrant of any other Construction.

Besides the Description of the Divisions, on the Arch already given in *Page 8* and *9*, there remains yet to be explained, the upper Arch of 45 Degrees, *See Fig. 6*, which represents a Part thereof. This is numbered from the right Hand towards the Left, at every single Degree, 1 2 3 4, &c. to 45, which are the under, Row of Figures, and in the upper Row of Figures, back again by 45 46 47 48, &c. to 90 Degrees, which compleats the Quadrant. The Course, or any other Angle, to be used with the 500 Parts on the side Index and Square, is always to be worked upon this upper Arch.

The Points of the Compass are also distinguished upon this Arch, by capital Figures, I. II. III. &c. from the Right-Hand towards the Left in the under Row, to 45, which is 4 Points, and from thence in the upper Row, back again to 90, which is 8 Points, by V. VI. VII. as at W, *Fig. 6*. The Quarter Points are distinguished from the Degrees, by a single Dot, half a Point by two Dots, and 3 Quarters of a Point by 3 dots, in counting from the Right-Hand towards the Left; but when the Course is above 45 Degrees, or 4 Points, then the Points, as well as the Degrees, must be reckoned the contrary way, from 45 Degrees, towards the Right-Hand, where the Quarter Points are expressed by three dots, the Half Points

before, by two Dots, and the three-Quarters of a Point by one Dot. Thus much for the Graduation of the Arch.

The Side AB, the Index AE, and Square YX, *Fig. 5*, are each of them actually divided into 500 equal Parts, and numbered 10, 20, 30, &c. to 100, and are to be used as follows. If the Numbers given are under 10, call the 10 one, the 20 two, the 30 three, and so on to a 100; which, in this Case, represents 10, and the secondary Divisions will represent so many Parts of an Unite. But if the Numbers given are above 10, then the Figures, as they stand, are right. The secondary Divisions, are Unites, and the smaller ones, Parts of an Unite. Again, if the given Numbers are above 100, then every smaller Division, of the first Order, represents two, and the intermediate Space one Unite; those of the second Order must be called Tens, and those of the third Order, to which the Numbers are affixed, are Hundreds, which will run from Unity to one Thousand. Hence, if the Question is given in any Number under one Thousand, the Answer will be had to a single Mile; if the Data is above 1000, and you take its $\frac{1}{2}$, a $\frac{1}{3}$, or $\frac{1}{4}$, so as to bring it under a 1000, and then double, tripple, or quadruple the Answer, you will likewise have the Resolution in Miles, for almost any Number that can be wanted in the Practice of Navigation.

E

For

For the Conveniency of working with the Square, when the Numbers fall near the Center, the two Horizon Glas Vanes, G and H, together with the two Sight Vanes L and M, *Fig. 5*, are contrived to be unshipped or taken off; the two first, by unscrewing the Screws hh, which are seen in *Fig. 5*, and the two last, by drawing back the Hooks at L, and i, in the same Figure. Though this Provision is made, yet it will seldom happen that you will have Occasion to unship any more than the Glas H, and Sight M,

Preliminary Problems,

AND

GENERAL RULES,

FOR THE

Right Working with the UNIVERSAL OCTANT.

How to reduce Miles and Leagues, run either Northerly or Southerly, into Degrees of Difference, of Latitude, and the contrary.

TO reduce Leagues into Degrees of Difference of Latitude, divide them by 20, and to perform this Operation in a short Manner, cast off the right Hand Figure, and take Half of the remaining Number to the left Hand, and this Half will give the Degrees, and the Figure cut off, multiplied by 3, will be the Surplus Minutes. *Example*; If a Ship Sails Northward 62 Leagues, the Difference of Latitude will be 3 Degrees 6 Minutes; the Figure cut off, is multiplied by 3, because every League is equal to 3 Nautical Miles, or Minutes of a Degree, and 60 Nautical or Geographical Miles make one Degree; wherefore the Difference of Latitude in Miles is reduce

duced into Degrees by dividing by 60, and on the contrary, the Difference of Latitude in Degrees is reduced into Miles by multiplying by 60.

PROBLEM I. *Given both Latitudes, to find the Difference of Latitude.*

R U L E.

If the Latitudes are both the same way, their Difference is the Difference of Latitude.

But if one be North, and the other South, their Sum is the Difference of Latitude.

EXAMPLE I.

Latitude sailed from	— —	50. 20 N.
Latitude came too	— —	34. 35 N.
Difference of Latitude,	{	15. 45 in Deg. and Min.
		60
		945 in Miles.

EXAMPLE II.

Latitude sailed from	— —	47. 30 N.
Latitude come into	— —	20. 15 S.
The Sum is the Difference of Latitude.	{	67. 45 in Deg. and Min.
		60
		4065 in Miles.

PRO-

PROBLEM II. *Given one Latitude, and the Difference of Latitude, to find the other Latitude.*

R U L E.

If a Ship Sails from the Equator, she increases, but if she Sails towards the Equator, she decreases her Latitude.

1st Therefore if the Latitude sailed from, and Difference of Latitude made, are both the same Way, their Sum will be the required Latitude.

2^d. And when one is Northerly and the other Southerly, their Difference will be the Latitude sought.

3^d. But when the Difference of Latitude, is greater than the Latitude sailed from, the Ship will have passed the Equinoctial; then, in this Case, subtract the Latitude sailed from, from the Difference of Latitude made, and their Difference will be the Latitude of the Place the Ship is in on the contrary Side of the Equator.

EXAMPLE I.

To the Latitude Sailed from	—	40.	32 N,
Add the Difference of Latitude made	750 = 12.	30	Nly.

Their Sum is the Latitude the Ship is in	53.	39 N.
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Ex-

EXAMPLE II.

From the Latitude sailed from	—	50.	15 N.
Take the Difference of Latitude 876	=	14.	36 S.
Remains the Latitude the Ship is in		35	39 N.

EXAMPLE III.

From the Difference of Latitude made	25.	35 S.
Take the Latitude sailed from	— 13.	20 N.
Remains the Latitude come into	— 12.	15 S.

In PLAIN, MIDDLE-LATITUDE, and
MERCATORS Sailing.

When the Course is given, and the Angle thereof, under 45 Degrees, always count the Difference of Latitude on the Side, and the Departure on the Square.

But when it is above 45 Degrees, then count the Difference of Latitude on the Square, and the Departure on the Side.

The Distance run is always counted upon the Index, and the Course upon the upper Circle of Degrees upon the Arch.

* * * Also take Notice, when the Course is required, that if you count the Difference of Latitude on the Side, and Departure on the Square, and your Numbers so counted will agree with the

the Index, the required Course will be under 45 Deg. but, if the Numbers on the Sides of the Triangle, will not correspond with the Index without removing the Index beyond 45 Degrees, then change their Situation by counting the Difference of Latitude on the Square, and the Departure on the Side, and you will have the Angle of the desired Course above 45 Degrees.

Again, in finding the Course, if the given Numbers are so small as to fall near the Center of the Octant, it is best to multiply them both by 2, 3, 4, 5, &c. and then work as before. The Angle of the Course will, by this Means, be better determined, only the required Side of the Triangle, must be divided by the same Number for the Answer.

In Parallel Sailing.

If the given Latitude is under 45 Degrees, count the Distance on the Side, and if it be above 45 Degrees, count the Distance on the Square; in both Cases you will have the Difference of Longitude upon the Index.

In

In Middle-Latitude Sailing.

If the Angle of the Middle Latitude is under 45 Degrees, count the Departure on the Side, if above 45 Degrees, count it on the Square; in both Cases you will have the Difference of Longitude upon the Index.

In Mercators Sailing.

When the Angle of the Course is under 45 Degrees, count the Meridional Difference of Latitude on the Side, and you will have the Difference of Longitude on the Square.

But if the Angle of the Course is above 45 Degrees, then count the Meridional Difference of Latitude on the Square, which being moved to Intersect the Index will give on the Side the required Difference of Longitude.

Also in finding the Course, if the Numbers fall out so, that when the Difference of Longitude, counted upon the Square, and the Meridional Difference of Latitude is counted on the Side, will compare together, then the Course is under 45 Degrees. But,

If they will not compare, change them by counting the Difference of Longitude on the Side, and the Meridional Difference of Latitude on the Square, and you will find the Course on the Arch, to be reckoned amongst the upper Row of Figures, above 45 Degrees.

Plain

PLAIN SAILING.

In Plain Sailing, the Distance, Difference of Latitude and Departure, form a Right Angled Triangle, in which the Angle opposite to the Departure, is the Course, and the other its Compliment.

When the Course is under 45 Degrees, or 4 Points of the Compass, you must reckon the Difference of Latitude upon the Side of the Quadrant, the Departure on the Square, and the Distance on the Index; the Course itself is always to be counted upon the Arch.

But when the Course is above 45 Degrees, or 4 Points of the Compass, then you must remember to count the Difference of Latitude upon the Square, and the Departure on the Side; the Course, in all Cases, on the Arch, and Distance on the Index.

In this Improvement of the Octant, the Point or Center C, *Fig. 5*, in all the Cases of Navigation, represents the Point of Departure, or, in other Words, the Place from whence the Ship is supposed to sail; the Instrument itself very elegantly represents an Eighth Part of the Horizon, in the following Manner; when the Course is under 45 Degrees, or 4 Points of the Compass, Then the Side AB, *Fig. 5*, represents the Meridian, and the Square YX, the East and West Line.

F

But

But if the Course is above 45 Degrees, or 4 Points of the Compass, then the Square YX, represents the Meridian, and the Side AB, the East and West Line.

Hence it will be very easy to comprehend the natural Use of this Instrument, from a due Consideration of what has been already said; by which Means the Reader will plainly see, that all the different Varieties of Right-Angled Triangles, may be represented by it, wherein the Index, set to any Direction, will represent the Hypothenuse, and its Length may always be determined by the Divisions thereon, which are equal amongst themselves, and with the same Facility, you may also have the Determination of the two other Sides, by Means of the other Lines engraved on the Side of the Octant, and on the Edge of the Square, which are also divided into the same equal Parts.

Plain Sailing, CASE I.

One Latitude, Course, and Distance, given to find the other Latitude and Departure.

EXAMPLE,

A Ship, from the Latitude of $50^{\circ} 00' N.$ sails upon the 3d Rumb, or N E b N, to the Distance of 65 Miles, what Latitude is the Ship

Ship in? and how far has she departed from her former Meridian?

Set the Index to the Course, which is 3 Points, and slide the Square until its Edge cut the Distance run, counted on the Index, which is 65 Miles, and, as the Angle of the Course is under 45 Degrees, you will have the Difference of Latitude 54 Miles on the Side, cut by the Edge of the Square, and the Index will point out, on the Square, the Departure, 36. 1, then, to find the Latitude the Ship is in, because she sailed from a North Latitude Northerly,

To the Latitude sailed from	— —	50. 00 N.
Add the Difference of Latitude	— —	54. Miles.

The Sum is the Latitude come to, 50. 44.

Plain Sailing, CASE II.

Given both Latitudes and Course to find the Distance and Departure,

EXAMPLE.

A Ship at Sea, in the Latitude of $45^{\circ} 25'$, N. after having sailed upon a Course N E b N, $\frac{1}{2}$ Ely. is found, by Observation, to be in the Latitude of $46^{\circ} 55'$ N. required her Distance and Departure, made good on that Course.

First, for the Difference of Latitude, as the two Latitudes and Course are both Northerly,

F 2

From

From the Latitude arrived at ——— 46. 55 N.
Take the Latitude sailed from. ——— 45. 25 N.

Remains the Diff. of Lat. $\left\{ \begin{array}{l} \text{in Deg. \& Min.} \quad 1. \quad 30 \quad N. \\ \text{in Miles.} \quad \underline{\quad 90 \quad} \end{array} \right.$

Here it will be necessary to observe that when, upon the first Attempt to work any Question, the Triangle should appear not to be compleat, by the Square falling beyond the Divisions upon the Index, as it does in the present Case.

The Course, which is $3 \frac{1}{2}$ Points, being under 45 Degrees, I set the Index thereto, by the Rule in Page 36, which shews me to count the 90 Miles of Difference of Latitude on the Side of the Universal Octant. Therefore, applying the Square to the aforesaid Number on the Side, I find its Edge reaches beyond the Divisions on the Index, from whence I am to get the Distance failed.

Now, to obviate this Difficulty, as well in the present as in any other subsequent Example, take half, a third, a fourth, &c. of the given Numbers, to which, apply the Square, and then double, triple, or quadruple the Numbers found, and you will have the true Answer.

Therefore, to solve the present Case, the Difference of Latitude being 90, its half 45, to which upon the Side, I apply the Square, the Index being first set to the Angle of the Course upon

upon the Arch, as before directed, and the Edge of the Square will cut upon the Index, 58. 4, the Double of which 116. 8, is the true Distance required, and on the Square you will have 36. 9, for the $\frac{1}{2}$ of the Dep: which being doubled, is 73. 8, the true Departure.

N. B. these Cases happen but very seldom, but that the Reader might see the most troublesome Part at first, I have chose those Numbers in this Place, that the Instrument might the sooner become familiar.

Plain Sailing, CASE, III.

One Latitude Course, and Departure given, to find the other Latitude and Distance.

EXAMPLE.

A Ship sails from the Latitude of $40^{\circ} 10' N.$ N E b N $\frac{1}{4}$ Ely. until her Departure be 33 Miles, what is the Latitude the Ship is in, and her Distance sailed?

Set the Index to the Course, which is $3\frac{1}{4}$ Points, and as it is under 45 Degrees, I slide the Square until the Index cuts 33 Miles, the Departure counted on the Square, and at the same Time you will have the Distance upon the Index 55. 5 Miles, and on the Side 44. 6 Miles, for the Difference of Latitude; then, because the Course is the same Way with the Latitude.

To

upon the Index, as before directed, and the
To the Latitude sailed from ——— 40. 10 N.
add the Diff. of Latitude made ——— 44. 6
 The Sum is the Latitude come into, 40. 54. 6 N.

Plain Sailing, CASE IV.

*Both Latitudes and Distance given to find the
 Course and Departure.*

EXAMPLE.

A Ship at Sea in the Latitude of 50° 00' N.
 sails between the North and East until her
 Distance be 65 Miles, and then, by Observa-
 tion is found to be in Latitude, 50° 54'; what
 is her Course and Departure?

<i>From the Latitude sailed to</i>	—	50. 54
<i>Take the Latitude sailed from</i>	—	50. 00

Remains the Difference of Latitude ——— 54. Miles

Set the Square to 54 Miles, the Difference
 of Latitude on the Side, where, hold it fast,
 and move the Index until 65 Miles, the Dis-
 tance counted on the Index, intersect the Edge
 of the Square, and the Nonius R, will give
 33° 50', the Angle of the Course, and on the
 Square you will have 36. 2 Miles the De-
 parture,

Plain

Plain Sailing, CASE V.

One Latitude Distance and Departure given, to find the other Latitude and Course.

EXAMPLE.

A Ship sails from the Latitude of $12^{\circ} 10' N.$ between the North and West 96 Miles, until her Departure be 53 Miles, I demand the Course and Latitude the Ship is in.

Slide the Square, and move the Index, until the Distance 96 Miles, counted on the Index, intersect the Departure 53 Miles counted on the Square; then on the Arch you will have $33^{\circ} 32'$ for the Course, and on the Side 80 Miles for the Departure, equal to $1^{\circ} 20'$. Therefore, to find the Latitude the Ship is in, as she sailed from a North Latitude Northerly.

To the Latitude sailed from	—	$12. 10 N.$
Add the Difference of Latitude made.		$1. 20 Nly.$

Their Sum is the Latitude required	$13. 30$
------------------------------------	----------

Plain

Plain Sailing, CASE, VI.

Both Latitudes, or rather the Difference of Latitude and Departure given, to find the Course and Distance.

A Ship at Sea in the Latitude of $44^{\circ} 50' N.$ is bound to a Port in the Latitude of $42^{\circ} 56' N.$ North, the Departure, by Estimation, being 64 Miles East, I would know the direct Course, and the Distance from the Ship to her Port.

To find the Difference of Latitude,

From the Latitude the Ship is in — $44^{\circ} 50' N.$

Take the Latitude bound to — $42^{\circ} 56' N.$

Remains the Difference of Latitude. $1^{\circ} 54' N.$ = 114 Miles

Then slide the Square to the Difference of Latitude 114 Miles, counted on the Side, and move the Index 'till it intersect the Departure 64, counted on the Square, and on the Arch you will have $29^{\circ} 19'$ for the Course, which falling between the South and East, is nearly S S E $\frac{1}{2}$ East, and 130. 4 Miles for the Distance Run.

N. B. As the Difference of Latitude 114, happens to fall so near the Center, it will be the best Way in this, and all such like Cases, to

to take $\frac{1}{2}$ of each of the given Numbers, and double the Answer, by which means the Angle of the Course will be better determined.

EXAMPLE.

*The Difference of Lat. 114 } its half { 57
Departure 64 } { 32*

The Square set to 57 on the Side, and the Index brought to coincide with 32 counted upon the Square, will give $29^{\circ} 19'$ on the Arch, for the Course, and 65. 2 on the Index, the Double of which is 130. 4 Miles the true Distance, as above.

Of a TRAVERSE, or Compound Course.

As the Universal Octant is very ready in working a Traverse, I shall here give an Example of 24 Hours Run, in the Manner it is generally placed upon the Log-Board, and shew how it may be taken off, and worked by this Instrument.

Suppose a Ship at Sea, bound to the Northward, steers away upon a North-East Course, but meeting with contrary Winds, makes several Courses, as follows.

LOG-BOARD.				
H	K	HK	Courses.	Winds.
2	4		NE	NW
4	3	1	ENE	N $\frac{1}{2}$ E
6	3			
8	3			
10	3	1	E $\frac{1}{2}$ N	NNE
12	4			
2	4	1		
4	3		ESE $\frac{1}{2}$ E	NE
6	3	1		
8	4			
10	5		NbW $\frac{1}{2}$ W	
12	4	1		

In this Table there are five Columns, the first marked H, shews the Hours, the second Knots, the third $\frac{1}{2}$ Knots; the fourth Column contains the Courses steered by the Compass, the fifth shews the Point of the Compass the Wind is upon.

As it is the usual Way to set down the Courses and Distances every Hour, or every two Hours; I shall, for Brevity sake only, set them down to two Hours, beginning the Reckoning from the Noon of one Day, and continuing it to the Noon of the next Day, upon the Log-Board.

They generally take from the Log-Board, every Day at Noon, the Courses and Distances, &c. marked thereon, from which they compute

pute the Difference of Latitude and Departure for each Course; and these, together with the Courses and Distances, are set down as in the following Traverse Table.

In this Example the Log is supposed to be hove every two Hours, and the Courses set down accordingly; Therefore, the Knots, and Parts of a Knot for each Course, must be added together, and the Total doubled, to give the Number of Miles upon each respective Course.

EXAMPLE.

In the first Line of the foregoing Log-Board is 4 Knots N E, which being doubled, is 8 Miles for the Distance upon that Course.

The first Course being N E 8 Miles, the Wind large; therefore lay the Index upon 4 Points, or 45 Degrees, and slide the Square till it intersect the Distance counted upon the Index, and you will have the Departure 5. 68 Miles, and on the Side 5. 68 Miles, for the Difference of Latitude; the Dep. must be set in the North Column, and the Difference of Latitude in the East Column, because the Course is between the N. and E.

N. B. The Distance run being under 10 Miles, I counted it amongst the grand Divisions, calling 10 one, 20 two, and 80 eight; to which the Square being set, I read off the Answer amongst the larger Divisions, both upon the Square and Side,

G 2

which

which is at 5. 6; calling the 50 but 5, and 10ths, and 8 of the smaller Divisions, which, in this Case, is five Miles, and 68 hundredth Part of another Mile.

TRAVERSE TABLE.

Courses.	Dist.	N	S	E	W
NE	8	5.68		5.68	
E b N	19	3. 7		18. 6	
E $\frac{1}{2}$ S	24		2. 4	23. 9	
SE b E $\frac{1}{2}$ E	21		9. 9	18. 5	
N N W $\frac{1}{2}$ W	19	16. 8			8. 9
		26. 18	12. 3	66. 68	8. 9
		12. 3		8. 9	
Diff. of Lat.		13. 88		57. 78	Dep.

The second Course is E b N, 19 Miles, the Course steered is E N E, the Ship lying within $5 \frac{1}{2}$ Points of the Wind, and allowing one Point for Leeway, the Course is E b N, which is 7 Points, to which, upon the Arch, place the Index, and slide the Square to the Distance 19 Miles, and because the Course is above 45 Degrees, you will have the Difference of Latitude upon the Square, 3. 7, to be placed in the North Column, and on the Side, the Departure 8. 6, to be placed in the East Column.

N. B. Here the Distance 19 Miles being near the Center, you may double it, and halve the Answer, which will remove the Square

Square farther from the Center: for Example, its Double 38 counted upon the Index, and the Square brought thereto, will give, on the Square, 7. 4, the Half of which is 3. 7 the Difference of Latitude, and on the Side 37. 3, which halved, is 18. 6 the Departure.

The third Course, allowing one Point for Lee-way, as before, is E. $\frac{1}{2}$ a Point S by. and the Distance 24 Miles: Therefore, lay the Index to 7 $\frac{1}{2}$ Points, and slide the Square to 24, the Distance counted on the Index, and you'll have the Difference of Latitude 2. 4 Miles on the Square, because the Course is above 45 Deg. and on the Side 23. 9 for the Departure; the first is to be put in the S. and the second in the E. Column.

What hath been already observed in these 3 Courses, is to be attended to in all the rest, by which Means this Traverse will be filled up on setting down under their proper Titles, in a Line with each respective Course, as follows: The Difference of Latitude in the North Column, if the Course be Northerly, and in the South Column if it be Southerly; the Departure must be set down in the East Column, when the Course is Easterly, and in the West Column when the Course is Westerly: Hence the Totals of the several Columns will shew the Northings, Southings, Eastings, and Westings, the Ship has made upon that 24 Hours Run: Therefore, if the Sum of the Northings

exceed the Sum of the Southings, the Ship has made Northerly just as much as the Excess 13.88 Miles; and if the Sum of the Eastings exceed that of the Westings, she has sailed Easterly 57.78; or, on the contrary.

By this Method the Mariner finds his Difference of Latitude and Departure in working any Day's Work at Sea; and from the Difference of Latitude and Departure thus obtained, we find the Distance, Course, and Latitude, by dead Reckoning, Meridian Distance, and Longitude made; which shall be farther explained in the following Discourse.

Then to find the direct Course and nearest Distance from the Place where the Ship began this Traverse to that where she is now supposed to be, the Difference of Latitude being 13.88 Miles N. and the Departure 57.78 Miles E. slide the Square to the Departure 57.78, counted on the Side, and count the Difference of Latitude 13.88 upon the Square, to which bring the Index, and it will cut $76^{\circ}.28'$ Degrees on the Arch, nearly 7 Points from the Meridian E b N. and the Distance Run will be on the Index 59.3 Miles.

From a through Knowledge of the foregoing Rules, you may, with the greatest Ease and Readiness, work any 24 Hours Traverse, and also reduce it to one Course and Distance, made good upon the whole by the Case 6th of PLAIN SAILING, and also find the Course and Distance to the intended Port.

PAR-

PARALLEL SAILING.

As the Parallels of Latitude sensibly diminish in Proportion as they draw nearer to the Poles, consequently a Degree on any one of them must be less than a Degree upon the Equator, and the Degrees of every other Parallel nearer the Poles, less than those of another, which is somewhat nearer the Equator than itself.

PARALLEL SAILING, CASE I.

The Distance sailed in any Parallel of Latitude given, to find the Difference of Longitude, and Longitude come into.

EXAMPLE I.

A Ship in the Latitude of $40^{\circ} 00'$ North, sails 153 Miles due East, how much is her Difference of Longitude?

Set the Index to $40^{\circ} 00'$, the Latitude counted upon the Arch, and slide the Square to 153 counted upon the Side; then the Edge of the Square will cut upon the Index 200 Miles, the Difference of Longitude required, equal to $3^{\circ} 20'$.

Ex-

EXAMPLE II

A Ship at Sea in the Latitude of $55^{\circ} 36' N.$ sails due West 685. 6 Miles, what is her Difference of Longitude?

Set the Index to the Latitude $55^{\circ} 36'$ upon the Arch, and slide the Square until the half of 685. 6 Miles, which is 342. 8, counted upon the Square, intersect the Index, and, at that very point upon the Index, you will have 606. 5, the Double of which 1213. 0 is the Difference of Longitude required, equal to $20^{\circ} 13'$.

I have chose these Numbers on purpose to variegate the Uses of the Instrument, that no Case might happen but what the Rules would solve.

Note also, that the Distance in the first Example, was counted upon the Side, because the Angle of the Latitude was under 45 Degrees; and in the second Example the Distance was counted upon the Square, because the said Angle of the Course was above 45 Degrees: And in all Cases of this kind, the Distance must be counted either on the Square or Side, and the Difference of Longitude will be constantly found upon the Index.

The Distance was halved in the second Example, because when the Index was set to the Angle of Latitude, and the Square applied in order to make the Distance, 685. 6, intersect the Index; the aforesaid Number, when counted

counted on the Square, fell beyond the Limits of the Index when set to that Angle; therefore, its half was taken and applied, as above, to the Index, and then, the Answer doubled, gave the Difference of Longitude sought.

Therefore, I shall desire the Reader to remember once for all, in this or any other like Example, either on the Square, the Side or the Index; to take a half, a third, a fourth, &c. and then to double, triple, or quadruple the Answer, which will, in almost all the Cases where the Numbers happen to run high, give the Answer, quite as exact as it can be taken from the Tables.

PARALLEL SAILING, CASE II.

Difference of Longitude and Distance given, To find the Latitude of the Parallel.

EXAMPLE

A Ship sails due West, 1870. Miles, and then her Difference of Longitude is 2910', what Latitude is the Ship in?

Count 1870 Miles upon the Square, and 2910 Miles upon the Index, and move both the Index and the Square until these two Numbers intersect each other, and the Index will then shew the Latitude of the Place upon the Arch, $50^{\circ} 00'$.

H

PAR-

PARALLEL SAILING. CASE III.

Difference of Longitude and Parallel of Latitude given, to find the Distance.

EXAMPLE.

A Ship in the Latitude of $55^{\circ} 30' N$. sails on that Parallel directly West, until her Difference of Longitude is $13^{\circ} 40'$, what Distance has she sailed upon that Parallel?

The Difference of Longitude reduced into nautical Minutes, is 820, which is the Distance upon the Equator, between the Meridian sail'd from, and the Meridian come to.

Set the Index to the Latitude of the two Places, which is $55^{\circ} 30'$, and slide the Square until it cut 820, counted upon the Index, and then, on the Square, you will have 465 Miles, the Answer for the Distance between the two Places.

Hence, the Number of Miles answering to a Degree of Longitude in any Parallel, of Latitude may be found by this Case, and thereby, such a Table as is frequently put into the Books of Navigation, for reducing the Minutes of Longitude in any Parallel of Latitude, into geographical Miles, and the Contrary, may, by this Instrument, be readily made, viz.

THE

THE RULE.

Set the Index to the Latitude, and slide the Square 'till its Edge cut 60, counted upon the Index; then, if the Angle of the Latitude is under 45 Degrees, you will have the Number of Miles, in that Parallel, upon the Side; but if the Angle of Latitude exceed 45 Degrees, then the Miles contained in one Degree, on that Parallel, will be found on the Square.

EXAMPLE I.

How many Nautical Miles make one Degree, in the Latitude of $51^{\circ} 32'$?

Set the Index to $51^{\circ} 32'$ upon the Arch, and slide the Square to 60, counted upon the Index, and then the Index will cut upon the Square 37. 40.

N. B. Here the Answer was given on the Square, because the Angle was above 45.

EXAMPLE II.

How many Nautical Miles make one Degree, in the Latitude of $32^{\circ} 27'$.

Set the Index to the Latitude, $32^{\circ} 27'$, and slide the Square to 60 upon the Index, then, on the Side, because the Angle is under 45, you will have 50. 6, which is 50 Miles and $\frac{6}{10}$ of another Mile.

H 2

From

From what has been said in the 3 foregoing Cases, the following Problem may be solved.

PROBLEM.

Given the Distance between any two Meridians in any given Parallel of Latitude, to find their Distance in any other Parallel.

EXAMPLE I.

Suppose two Ships, from the Latitude of $60^{\circ} 00'$ N. at 800 Miles Distance from each other, sail due South until they come into the Latitude of $40. 00$ North, how far are they assunder?

Set the Index to the Latitude of 60, and slide the Square 'till the half of the given Distance, intersect the Index, which will be 800; then move the Square, to the other Latitude of $40. 00$, and slide the Square 'till it cut 800 upon the Index, and you will have the Answer, 613 on the Side, because this last Latitude is under 45 Degrees, the Double of which, is 1226, Miles, their Distance assunder.

EXAMPLE II.

Suppose two Ships from the Latitude $26^{\circ} 40'$ S. distant assunder, 1878 Miles, sail due North 4560 Miles, into the Latitude of $49. 20$ N, let

let it be required to find their Distance from each other.

Set the Index to the first Latitude 26. 40, and slide the Square to the third Part of 1878 which is 626 counted on the Side, and it will cut on the Index 700, then move the Index to the other Latitude 49. 20, and slide the Square to 700 on the Index, which will cut the Square at 456. 3, which being multiplied by 3, gives 1369 Miles, the Distance required.

MIDDLE-LATITUDE SAILING.

We have already shewn, in Parallel Sailing, how, from the Difference of Longitude given, between two Places, to find the Miles of Easting and Westing, and the Contrary; but when the Difference of Longitude cannot be counted into Miles of Easting and Westing upon the Parallel of either Place, because they are not upon the same Parallel; for if you reduce them to the greater Latitude, they will be too small, or upon the lesser Latitude they will be too large; therefore, the Practice is to find a Middle Parallel of Latitude, between the two Places, by adding the two Latitudes together, and taking half their Sum, which will be the Latitude of the Middle Parallel, upon which, the Difference of Longitude, and Miles of Easting and Westing, are to be counted,

How

How to find the Difference of Longitude, by comparing the Departure and Middle Latitude together.

EXAMPLE I.

A Ship sails from the Latitude of $42^{\circ} 00'$, and hath made 61 Miles Departure, either Easterly or Westerly, I demand the Difference of Longitude.

Set the Index to the Latitude $42^{\circ} 00'$, and slide the Square to 61 Miles, the Departure counted upon the Side, (because the Angle is under 45 Degrees, and you will have, on the Index, 82. 4 Miles, the Difference of Longitude required.

EXAMPLE II.

A Ship sails from the Latitude of $50^{\circ} 30'$, and hath advanced 105 Miles towards the East or West, I demand the Difference of Longitude.

Set the Index to $50^{\circ} 30'$, the Angle of Latitude, and slide the Square 'till 105 counted upon the Square, intersect the Index, and at that Point, upon the Index, you will have 166 your Difference of Longitude required.

* * If the Angle of the Middle Latitude is under 45 Degrees, always count the Departure on the Side ; but if it be above 45 Degrees,

Degrees, count it on the Square, in both Cases you will have the Difference of Longitude upon the Index.

MIDDLE-LATITUDE SAILING, CASE I.

One Latitude, Course and Distance sailed given, to find the other Latitude, and Difference of Longitude.

EXAMPLE.

A Ship from the Latitude of $40^{\circ} 45'$ North, sails 60 Leagues upon the third Rumb, or NE b N, what Difference of Longitude hath she made? and what Latitude and Longitude is she come to.

* * In Middle Latitude, and in Mercators Sailing, I would advise the Reader always to write down as below, not only what is given; but also every other Thing which results from the aforesaid, or any other *Data*, as well as every Thing you are to find, which, if you always do in the same regular Order, it will be a constant Remembrancer of the Rules herein laid down, altho' not one of them are mentioned. This being done opposite to their respective Articles, write down the given Quantities, and also what results from them which need no working, and then

then fill up the required ones, as you work the Question.

Latitude sailed from N.	40. 45	50. 00 Leagues Diff. of Lat.
Difference of Lat. N.	— 2. 30	33. 3 Departure East.
Lat. come into N.	— 43. 15	40. 45
Middle Latitude	— 42. 00	43. 15
Longitude sailed from	— 15. 20	
Difference of Long. East	2. 15	84. 00
Longitude come into	— 17. 35	
Dist. sailed 60 Leagues		42. 00 Middle Latitude
Course 3 Points N E b N		45. 00 Leagues Diff. of Long.

Having thus wrote down all the Necessary Articles set down opposite to their respective Names, the Quantities of your *Data*, viz. your Latitude sailed from $40^{\circ} 45'$ and its Result, which is also given, altho not expressed in the *Data*, and is the Longitude sailed from $15^{\circ} 30'$. Then,

To find the Difference of Latitude, by the first Case of Plain Sailing, Set the Index to the Angle of the Course, which is 3 Points, and slide the Square to 60, the Distance counted on the Index, and you will have the Difference of Latitude, 50 Leagues, on the Side, because the Angle of the Course is under 45 Degrees, this I set down upon the Right-Hand of the foregoing Articles, having first drawn a Line to Part them.

The Index and Square remaining as above, you will also have 33. 3 Leagues the Departure or Easting, counted on the Square, which, set down under the Difference of Latitude just found.

next

Next it will be easy, without making more Figures than needful, to bring the said 50 Leagues into Degrees and Minutes by the Rule in Page 33. Therefore, casting off the last Figure, and taking the Half of the Right-hand Figures, &c. it will be found equal to $2^{\circ} 30'$, which I place against its own Article, the Difference of Latitude.

Now, as before, without writing down these Numbers again, I add the Difference of Latitude to the Latitude sailed from, as the Numbers stand in the Articles, and write down the Sum, 43. 15, against its own Title, for the Latitude come to. Again, on the Right-hand Side of the Line, set down the two Latitudes, and add them together, taking half their Sum for the Middle Parallel of Latitude, which is 42. 00, and place this also, against its Title.

The next Thing we have to do is to reduce the 33. 3 Leagues, into Leagues of Longitude, for the Lesser, or Middle Parallel, as follows.

Lay the Index to 42. 00, and move the Square till it comes to 33. 3 counted upon the Side, and the Edge of the Square will cut upon the Index 45 Leagues, equal to $2^{\circ} 15'$, the Difference of Longitude, which, because the Course was Easterly, added to the Longitude sailed from, makes $17^{\circ} 35'$ for the Longitude the Ship is in, which, being also wrote down against its Article, the Example is intirely resolved.

I. MID-

MIDDLE LATITUDE SAILING. CASE I.

EXAMPLE II.

A Ship sails from the Latitude of $50^{\circ} 30' N.$ and $359^{\circ} 6'$ Longitude, Course S E 3° Easterly, or $48^{\circ} 00'$ to the Distance of 40 Leagues, required the Latitude and Longitude the Ship is in.

Latitude sailed from N.	50. 30	Leagues	
Difference in Latitude S.	1. 20	26. 7	Diff. Latitude
Latitude come to N.	49. 10	29. 6	Departure
Middle Latitude	— 49. 50		
Long. sailed from	— 359. 6	50. 30	
Diff. in Longitude E.	2. 18	49. 10	
Longitude come into	361. 24		
Distance sailed 40 Leagues.		99. 40	
Course S E 3 Deg. $E\lambda = 48^{\circ} 00'$			
		49. 50	Midd. Latitude.
		46. 0	Leagues of Long. answering to the Mid. Parallel.

After having disposed of the Articles as above, lay the Index upon the Course $48^{\circ} 00'$, and slide the Square to 40 Leagues on the Index, for the Distance run, and you will have, on the Square, 26. 7, the Difference of Latitude, and on the Side, 29. 6 for the Departure.

* * Because the Angle was above 45, the Difference of Latitude was counted upon the Square, and the Departure on the Index. Now set these two Numbers on the Right-hand of the former Article, as was before directed.

The 26. 07 Leagues Difference of Latitude, are

are equal to $1^{\circ} 20'$, which being substracted from the Latitude sailed from, leaves the Latitude the Ship is in, $49^{\circ} 10'$, and the Sum of the two Latitudes being halved, gives $49^{\circ} 50'$, for the Middle Parallel.

To which set the Index, and slide the Square until 29. 6 Miles, the Departure counted on the Square, intersect the Index, and you will have, on the Index, 46 Leagues, which, reduced into Degrees, will be $2^{\circ} 18'$ the Difference of Longitude required, and being added to the Longitude sailed from, rejecting 360, will give $1^{\circ} 24'$ for the Longitude of the Place the Ship is in.

MIDDLE-LATITUDE SAILING, CASE I.

EXAMPLE III.

The Latitude sailed from, $55^{\circ} 00'$ S. Longitude $2^{\circ} 50'$ Course 5 Points Wly. or S W b W. Distance run 600 Miles.

Lat. sailed from	— 55. 00	333	Difference of Latitude
Diff. of Latitude	— 5. 33	500	Departure
Latitude come to	— 60. 33		55. 00
Middle Parallel	— 57. 46		60. 33
Longitude sailed from	362. 50		
Difference in Long.	15. 38		115. 33
Longitude come to	347. 12		
Distance sailed 600 Miles.			57. 46 Middle Parallel.
Course 5 Points Wly. or S W b W			938 Diff. of Longitude.

Set the Index to the Course 5 Points, and slide the Square till it intersect the Distance 600 Miles, counted upon the Index, and you will have the Difference of Latitude 333 Miles upon the Square (because the Angle of the Course is above 45 Degrees) and on the Side you will have the Departure 500 Miles West-erly,

The Difference of Latitude reduced into Degrees and Minutes is equal to $5^{\circ} 33'$, which in this Example must be added to the Latitude sailed from, because we have sailed farther from the Equator.

Then, to find the Difference of Longitude, set the Index to the Middle Parallel $57^{\circ} 46'$ found as before taught; and as it is above 45 Degrees, count the Departure 500 upon the Square, and you will have 938 on the Index for the Difference of Longitude, equal to $1^{\circ} 5^{\circ} 38'$ Wly.

The Longitude being lessened in sailing Westerly, as the Longitude sailed from was not large enough to make a Substraction, $362^{\circ} 50'$ was wrote down instead of $2^{\circ} 50'$, which is precisely the same Thing; and having found $347^{\circ} 12'$ for the Longitude come to, we are past the first Meridian, and arrived at $12^{\circ} 48'$ of Longitude on the Western Side thereof.

MIDDLE-LATITUDE SAILING, CASE I.

EXAMPLE IV.

Latitude sailed from $0^{\circ} 15'$ South, Longitude $15^{\circ} 30'$, Distance run $53\frac{1}{2}$ Leagues N N W, at which Place the Variation was 10 Degrees N Wly; the Latitude and Longitude of the Place the Ship is in being required.

Latitude sailed from S	0. 15	45. Leagues N. Diff. Lat.
Difference of Lat. N —	2. 15	28. 7 Leagues Departure
Lat. come to N —	2. 0	
Middle Parallel —	1. 0	
Longitude sailed from	15. 30	28. 7 Leagues Diff. Longitude
Difference of Longitude	1. 27	
Longitude come to —	14. 03	
Distance sailed $53\frac{1}{2}$ Leagues		
Course N N W. 2 Points		
Var. 10 Deg. Wly. makes the true Course 32. 40		

It is here supposed that the Variation of the Needle was 10 Degrees Westerly; whence it appears that the Course was N N W 10 Degrees Wly; therefore as N N W is 2 Points, or $22^{\circ} 30'$, the Variation being added thereto, makes $32^{\circ} 40'$; to which lay the Index for the true Course, and slide the Square to $53\frac{1}{2}$ Leagues counted on the Index for the Distance, and the Side will give 45 Leagues for the Difference of Latitude, whilst the Square gives 28.7 Leagues for the Departure.

The

The Latitude sailed from being $0^{\circ} 15'$ South; and as the Ship has advanced 45 Leagues towards the N, which being changed into Degrees, is $2^{\circ} 15'$, we have passed the Equator and come into 2° Degrees of North Latitude; thus we pass from one Hemisphere into the other every time we run near the Equator.

When the Latitudes are of different Denominations, that from whence the Ship sails, and that of its Arrival, the half of the greatest must be taken for the Middle Parallel.

Then set the Index to one Degree for the Middle Parallel, and slide the Square to the Departure, counted on the Side which is 28. 7 Leagues, and you will have on the Index 28. 7, the Difference of Longitude equal to $1^{\circ} 27'$.

MIDDLE-LATITUDE SAILING, CASE II.

Both Latitudes and Course given to find the Distance sailed, Difference of Longitude, and Longitude come to.

EXAMPLE I.

A Ship sails from the Latitude of $40^{\circ} 45'$ South Longitude 250 Degrees on a Course, S E b S, into the Latitude of $43. 15$ South, required the Distance, and Longitude arrived at.

Latitude sailed from S	40. 45	33. 3	Leagues Departure
Latitude come to S	— 43. 15	50.	Leagues Diff. Lat.
Difference of Latitude S	2. 30	40. 45	
Middle Latitude	— 42. —	43. 15	
Longitude sailed from	250. 00		
Difference of Longitude E	2. 15	84. 00	
Longitude come to	— 252. 15		
Distance in Leagues 60		42.	Middle Parallel
Course S E b S, or 3 Points		45.	Leagues Diff. of Long.

The

The several Articles being wrote down, as above, fill up those which are given with their proper Quantities and subtract one Latitude from the other for the Difference of Latitude, which is $2^{\circ} 30'$ equal to 50 Leagues.

Set the Index to the Course, which is 3 Points, and slide the Square to 50, the Difference of Latitude counted upon the Side, you will have 60 Miles upon the Index for the Distance, and on the Square 93. 3 Leagues for the Departure.

Then seek the Middle Parallel, as before taught, which will be $42^{\circ} 00'$; to which set the Index and slide the Square to 33. 3 counted upon the Side, the Edge will then cut 45° Leagues upon the Index for the Difference of Longitude equal to $2^{\circ} 15'$, which added to the Longitude sailed from, because the Course was Ely, will give the Longitude come to $252^{\circ} 15'$.

EXAMPLE II.

Latitude sailed from $50^{\circ} 30' N$; Longitude 1 Degree; and having run upon a S E Course when the Variation of the Compass was 3 Degrees N Wly, until the Ship was come into the Latitude of $49^{\circ} 10' N$. I demand the Distance, Run, Difference of Longitude, and Longitude come to.

Latitude sailed from N	50. 30	26. $\frac{2}{3}$ Leagues Diff. of Lat.
Latitude come to N	— 49. 10	29. $\frac{1}{3}$ Leagues Departure
Difference of Latitude S	1. 20	50. 30
Middle Parallel	— 49. 50	49. 10
Longitude sailed from	1. 00	—
Difference in Longitude	2. 18	99. 40
Longitude arrived at	3. 18	—
Distance sailed 40 Leagues		49. 50 Middle Parallel
Course S E 3 Degrees Ely		46. $\frac{1}{3}$ Leagues Diff. of Long.
Variation 3 Degrees N Wly		

In

In this Example the Variation of the Compass is supposed to be from the North 3 Degrees Wly, which hath sometimes caused the Mariner to mistake the Direction of the Course: For when the Variation is from the North Westerly, all the Points of the Compass, on the West Side, ought to decline towards the South, and all the Eastern points, towards the North: Thus, whilst we think to steer S E we actually run upon a Course S E 3 Degrees Easterly; therefore this last Course, which is equal to 48 Degrees, must be compared with $1^{\circ} 20'$ the Difference of Latitude, or, which is the same thing, with $26\frac{2}{3}$ Leagues; therefore placing the Index at 48 Degrees, move the Square till it gives $26\frac{2}{3}$ Leagues counted on the Square, and on the Index you will have 40 Leagues for the Distance sailed, and on the Side $29\frac{2}{3}$ Departure.

Then the Index being set to the Middle Parallel $49^{\circ} 50'$, move the Square to $29\frac{2}{3}$ Leagues Departure counted on itself, and it will shew on the Index 46 Leagues Difference of Longitude, equal to $2^{\circ} 18'$, which, as before taught, being added to the Longitude sailed from, will make $3^{\circ} 18'$, the Longitude the Ship is in.

EXAMPLE III.

A Ship sails from the Latitude of $0^{\circ} 15' S$, and Longitude 110 Degrees, upon a Course N N W 10 Degrees W, or $32^{\circ} 30'$, until she comes

comes into 2 Degrees of North Latitude. I demand her Distance, and Longitude come to.

Latitude sailed from S — 0. 15	29 $\frac{1}{2}$ Leagues Departure
Latitude come to N — 2. 00	45 Leagues Diff. of Latitude
Difference of Latitude — 2. 15	
Middle Parallel — 1.	
Longitude sailed from 110. 00	29 $\frac{1}{2}$ Difference of Longitude
Difference of Longitude W 1. 27	
Longitude the Ship is in 108. 33	
Distance 53 $\frac{1}{2}$	
Course NNW 10° W, or 32° 30	

The two Latitudes being of different Denominations, one North and the other South, must be added together to find their Difference.

For, properly speaking, the Quantity which we call Difference is rather the Interval between the two Latitudes. We sailed from 0°. 15' South Latitude, and are come into 2°. 00' North Latitude, and must therefore necessarily have advanced towards the North; or have changed our Latitude 2°. 15', which is equal to 45 Leagues Difference of Latitude; therefore set the Index to 32. 30 the Course, and slide the Square to 45, the Difference of Latitude counted on the Side and on the Index you will have 53 $\frac{1}{2}$ Leagues Distance, and 29 $\frac{1}{2}$ Leagues Departure on the Square, &c. The Middle Parallel being but one Degree, the Difference of Longitude will be the same as the Departure.

MIDDLE-LATITUDE SAILING, CASE III.

One Latitude, Course and Departure, given to find the other Latitude, Distance, and Difference of Longitude, with the Longitude come to.

EXAMPLE.

A Ship at Sea in the Latitude of $48^{\circ} 23' N$, and 323 Degrees Longitude sails S W by S, until her Departure be 123 Miles Westerly, What is her Latitude come to, Difference of Longitude, and Distance sailed.

Latitude sailed from	— $48. 23$	184	Diff. of Lat.
Lat. come to	— $45. 19$	123	Miles Departure
Difference of Lat.	— $3. 04$	$48. 23$	
Middle Parallel	— $46. 51$	$45. 19$	
Longitude sailed from	— $323. 00$		
Difference of Long.	— $3. 00$	$93. 42$	
Longitude come to	— $320. 00$		
Dist. sailed 221 Miles		$46. 51$	Mid. Par. of Lat.
Course S W by S 3 Points		180	Miles Diff. of Long.

Set the Index to the Course which is 3 Points, and because the Angle thereof is under 45 Degrees I count the Departure upon the Square, and therefore slide it until 123 Miles the Departure intersect the Index, at which Point of Intersection, counted upon the Index, you will have 221 Miles for the Distance; and on the Square you will have 184 Miles for the Dif-

Difference of Latitude equal to $3^{\circ}.04'$; and as the Ship is supposed to sail Southward she has decreased in Latitude; therefore having deducted the Difference of Latitude $3^{\circ}.04'$ found from the Latitude sailed from, there will remain the Latitude come to 45.19 ; then the Middle Latitude, found as before shewn, will be $46^{\circ}.51'$; to which set the Index, and as it is above 45, count the Departure 123 on the Square, sliding it till it meets the Index, and you will have on the Index 180 for the Difference of Longitude equal to $3^{\circ}.00'$, which taken from the Longitude sailed from, because the Course was Westerly, will leave the Longitude come to, $320^{\circ}.00'$.

MIDDLE-LATITUDE SAILING, CASE IV.

Both Latitudes and Distance given to find the Course, Departure, Difference of Longitude, and Longitude come to.

EXAMPLE I.

A Ship sails from the Latitude of $50^{\circ}.30' N.$ Longitude $35^{\circ}.10'$. The Distance run 45 Leagues between the South and East, until by Observation she is found in the Latitude of 49

K 2

North.

North. What is the direct Course and Difference of Longitude, &c.

Latitude sailed from N.	50. 30	33 $\frac{1}{2}$ Leagues Departure
Latitude come into N.	49. 00	30 Leagues Diff. Latitude
Difference of Latitude S.	1. 30	50. 30
Middle Latitude —	49. 45	49. 00
Long. sailed from —	35. 10	
Diff. in Longitude E.	2. 36	99. 30
Longitude come into	37. 46	
Rumb, or Course 48° 10' SE, 3		49. 45 Midd. Par. of Lat.
Deg. Easterly		
Distance 45 Leagues.		
		52. 8 Diff. of Longitude.

First find the Difference of Latitude, which is 1° 30' equal to 30 Leagues; then move the Square and Index until 30 Leagues, the Difference of Latitude counted on the Square intersect 45 Leagues the Distance counted upon the Index, and the Nonius R will give 48° 10' for the Course, or SE 3 Degrees Easterly, and at the same time you will have 33 $\frac{1}{2}$ Departure Ely. Next find the Middle Parallel, which is 49°. 45', to which set the Index, and slide the Square 'till 33 $\frac{1}{2}$ of its Parts intersect the Index, and it will give you 52. 8 thereon, for the Difference of Longitude, equal to 2°. 16'.

EXAMPLE. II.

Latitude sailed from 48°. 45', North Longitude 2°. 50', Distance run 160 Leagues between

tween the South and West, Latitude arrived at by Observation, $43^{\circ} 30'$, North; required the Course and Longitude come into.

Lat. sailed from N.	48. 45	105 Leagues Difference of Lat.
Latitude arrived at N.—	43. 30	121 Leagues Departure
Diff. of Latitude S.	— 5. 15	48. 45
Middle Parallel	— 46. 07	43. 30
Longitude sailed from	362. 50	
Difference in Long. W.	8. 42	92. 15
Longitude come to	354. 08	
Course $49^{\circ} 00'$ or SW. 4° Wly.		46. 07 Middle Parallel.
Distance 160 Leagues		174 Leagues Diff. of Long.

MIDDLE-LATITUDE SAILING, CASE V.

One Latitude, Distance, and Departure, given to find the other Latitude, Course and Difference of Longitude, together with the Longitude come to,

EXAMPLE.

A Ship sails from the Latitude of $50^{\circ} 00' N$. and Longitude, $165^{\circ} 00'$, between the South and West 150 Miles, until her Departure be 115 Miles; what is the other Latitude, Course, and Difference of Longitude?

Latitude sailed from N	50. 00	115. Miles Departure
Latitude come to N —	48. 24	96. Diff. of Lat.
Difference of Latitude S	1. 36	50. 00
Middle Parallel	— 49. 12	48. 24
Longitude sailed from	165. 0	
Longitude come to	162. 04	98. 24
Difference in Long. Wly	2. 56	
Distance sailed 150 Miles.		49. 12 Middle Parallel
Course S $50^{\circ} 07'$ Wly.		176. Diff. of Long.

Set

Set the Square to 115 the Departure counted on the Side, and move the Index until the Distance 150, counted thereon, intersect the Square; then, on the Arch, you will have the Course 50. 07, and, on the Square, the Difference of Latitude 96 Miles, whence the Latitude come to will be $48^{\circ} 24'$, and the Middle Latitude $49^{\circ} 12'$; to which, set the Index and slide the Square until 115, the Departure counted on the Square, intersect the Index, and at that Point of Intersection on the Square, you will have 176 for the Difference of Longitude.

MIDDLE-LATITUDE SAILING, CASE VI.

Both Latitudes and Departure given, to find the Course, Distance, and Difference of Longitude, together with the Longitude come to.

EXAMPLE.

A Ship sails from the Latitude of $40^{\circ} 45' N.$ and Longitude 354 between the N. and E. 'till she has made her Departure 100 Miles E. and is then found in the Latitude of $43^{\circ} 15'$ by Observation; required the Course, Distance, and Difference of Longitude?

Latitude sailed from	N 40. 45	100.	Miles Departure
Latitude come to	N — 43. 15	150.	Miles Diff. Lat.
Difference of Latitude	N 2. 30	40. 45	
Middle Parallel	— 42. 0	43. 15	
Longitude sailed from	354. 0		
Longitude come to	— 356. 15	84. 00	
Difference of Longitude	2. 15		
Distance	180 Miles.	42. 00	Middle Parallel
Course	$33^{\circ} 40'$ or NE b N	135.	Miles Diff. of Long.

First

First set the Square to 150, the Difference of Latitude counted on the Side, and move the Index 'till it intersect the Departure, 100 Miles, counted on the Square, then, on the Arch, you will have $33^{\circ} 40'$ for the Course, and on the Index 180 Miles for the Distance.

Then set the Index, to the Middle Parallel, $42'$ Degrees, counted upon the Arch, and slide the Square 'till it cut 100 Miles on the Side, and on the Index you will have 135 for the Difference of Longitude, equal to $2^{\circ} 15'$, which being added to the Longitude sailed from, because the Course was Ely. will give $356^{\circ} 15'$ the Longitude come to.

MIDDLE-LATITUDE SAILING, CASE VII.

Both Latitudes and Difference of Longitude given, to find the Course and Distance.

A Ship sails from the Latitude of $40^{\circ} 45' N.$ and Longitude $354^{\circ} 00'$ between the N. and E. until she is found in Latitude $43^{\circ} 15'$ and Longitude, $356^{\circ} 15'$. The Course and Distance is required?

Latitude sailed from N	40. 45	150 Miles Diff. Lat.
Lat. come to N	43. 15	135 Miles Diff. Long.
Difference of Lat. N	2. 30	40. 45
Middle Parallel	42. 00	43. 15
Longitude sailed from	354. 00	
Difference of Longitude	2. 15	84. 00
Longitude come to	356. 15	
Distance 180		42. 00
Course NE $\frac{1}{2}$ N		100 Miles Departure

The

The Difference of Latitude must be obtained as before taught, the Difference of Longitude, by subtracting one from the other, and is Ely. because the Longitude come to, is greater than the other.

Set the Index upon $42^{\circ}.00'$ the Middle Parallel counted on the Arch, and slide the Square to 135 Miles Difference of Longitude counted on the Index, and you will have 100 Miles on the Square for the Departure. Then,

To find the Course set the Square to the Difference of Latitude 150 counted on the Side, and move the Index until it intersect 100 Miles the Departure counted on the Square, and you will have the Distance 180 Miles on the Index, and the Course $33^{\circ}.10'$ upon the Arch, which is N E b N nearly.

EXAMPLE II.

A Ship sails from Latitude $58^{\circ}.45' N$, and Longitude $7^{\circ}.30'$ into Latitude $52^{\circ}.30' N$ and $354^{\circ}.54'$ of Longitude, required the Distance and Course, &c.

Lat. sailed from N	58. 45	756 Miles Difference of Long.
Lat. arrived at N	52. 30	58. 45
Difference of Lat. S	6. 15	52. 30
Middle Parallel	55. 37	
Longitude sailed from	367. 30	111. 15
Long. arrived at	354. 54	
Diff. of Long. W	12. 36	55. 37
Course S W $3.40 W$		426 Miles Departure
Distance 567 Miles		375 Difference of Lat.

In this Example the Difference of Latitude is Southerly, which diminishes the Latitude; and, instead of writing down $7^{\circ}. 30'$ for the Longitude sailed from, I have put $367^{\circ}. 30'$, this Augmentation being necessary that we might be able to find the Difference of Longitude in the shortest Way, and is West, because the Longitude is lessened, as is plain from the Numbers thereof; the Difference of Long. $12^{\circ}. 36'$ being equal to 756 Miles therefore set the Index to the Middle Parallel $55^{\circ}. 37'$, and slide the Square to 756 upon the Index, it will cut 426 upon the Square for the Departure, which must be compared with the Miles of Difference of Latitude 375, by counting 426 upon the Side, whereunto apply the Square, and move the Index till it cuts 375 on the Square, and the Point of Intersection on the Index will give 567 Miles for the Distance, and $48^{\circ}. 40'$ for the Course, which, as the Ship sailed from the North Westerly, is S W $3^{\circ}. 40'$ W.

EXAMPLE III.

A Ship at Sea sails from $5^{\circ}. 00'$ South Latitude, and $357^{\circ}. 0'$ Longitude, into $7^{\circ}. 00'$

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of

of North Latitude and $8^{\circ}.00'$ of Longitude.
The Distance and Course are required.

Lat. sailed from S.	5. 00	660 Miles Difference of Long.
Latitude arrived at N	— 7. 00	
Diff. of Latitude N	— 12. 00	
Middle Latitude	— 3. 30	
Longitude sailed from	357. 0	720 Miles Diff. of Latitude
Longitude arrived at	368. 0	659 Miles Departure
Difference in Long. Ely.	11. 0	
Course	42. 26	
Distance	977 Miles	

In this Example the two Latitudes are added together to obtain their Difference, because they are of different Denominations ; having crossed the Equator and sailed Northward, the Middle Lat. is found in taking the Half of the greatest Latitude, the Difference of Longitude is Easterly, because the Longitude is increased ; for 8 Degrees is the same Thing as 368 Degrees, which is greater than 357° Degrees. The 11 Degrees Difference of Longitude is equal to 660 Miles, and the Departure is found to be 659, almost the same Quantity, because of their Nearness to the Equator: Lastly, comparing the Difference of Latitude 720 Miles with the 659 you will have the Distance in Miles on the Index, and the Rumb as before shewn on the Arch.

MIDDLE-LATITUDE SAILING, CASE VIII.

One Latitude Departure, and Difference of Longitude given, to find the other Latitude, Course and Distance.

EXAMPLE.

A Ship sails from the Latitude of $50^{\circ} 46'$ N, Longitude 312 Degrees between the N and W until her Difference of Longitude be $3^{\circ} 12'$, and at the same time to have 126 Miles of Departure from her former Meridian. What is the Difference of Latitude, Course and Distance?

Latitude sailed from N	50. 46	126	Miles Departure W
Lat. come to	47. 14	212	Diff. Lat.
Difference of Lat.	3. 32	49. 00	Mid. Par. found
Middle Parallel	49. 00	2.	
Longitude sailed from	312. 00		
Difference of Longitude	3. 12	98. 00	its Double.
Longitude come to	308. 48	Sub. 50. 46	Lat. sailed from
Distance	246		
Course 30° , 50, or S S W 3° Wly		Rem. 47. 14	Latitude come to
		192	Miles Difference of Long.

First, to find the Latitude come to by the second Case of Parallel Sailing, counting 126 Miles the Departure on the Square, whereunto bring 192 Miles the Difference of Longitude counted on the Index, and you will have on the Arch 49 Degrees for the Middle Parallel.

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Therefore,

Therefore, as the Middle Latitude is equal to half the Sum of the two Latitudes, and the Sum of both Latitudes equal to double the Middle Latitude; then, consequently, if you subtract either of the Latitudes from the double of the Middle Latitude, the Remainder will be the other Latitude 47. 14, from whence we shall have the Difference of Latitude 3. 32 equal to 212 Miles.

Then slide the Square to the Difference of Latitude 212 counted upon the Side, and move the Index until it intersect the Departure 126 counted upon the Square, and you will have the Distance upon the Index 246, and on the Arch the Course $30^{\circ}. 50'$, which, because it is between the S and W, will be S S W $\frac{1}{4}$ Wly nearly,

From a thorough Knowledge of what has been here laid down, a Traverse may be easily wrought in Middle-Latitude Sailing.

Of a TRAVERSE, or COMPOUND COURSE.

In every Day's Run at Sea, it frequently happens that the Ship is obliged to change her Course, which puts the Navigator under the Necessity of working this particular Problem: To gain the direct Course and Distance of every 24 Hours run.

EXAMPLE.

EXAMPLE.

A Ship in the Latitude of $45^{\circ} 00' N$, and Longitude 110, having stem'd the following Courses when the Variation of the Compass was one Point from the North Ely; I demand the Latitude come to, Difference of Longitude and Longitude come to.

Courses Sailed,	Courses Corrected by Variation.	No.	Dist.	Diff. Lat.		Departure.	
				N	S	E	W
NNE	NE b N	3	100	83.2		55.5	
W b N	WNW	2	230	88.1			21.2
E	E b S	7	80		15.5	78.3	
				771.3	15.5	133.8	21.21
				15.5			133

155.8

79

After having disposed of the Articles, and filled up all the Quantities already known or given, first seek what Effect the Variation hath had on the Courses: in the first the Ship sailed NNE by the Compass, but as the Variation was Easterly, one Point or $11^{\circ} 15'$, it hath caused this Direction to answer to NE b N, which being wrote down for Use in the Columns under Courses Corrected, that is, we count the 100 Miles of the first Course not upon NNE, but upon NE b N, and we shall see how much we have advanced towards the North and East, the second Course W b N is changed
in

in the same Manner into W N W, and the third Course E is become E b S, then find your Difference of Latitude and Departure for each Course as before taught in the Traverse for Plain Sailing, Page 50.

After this add the Numbers in each Column into one Sum, and subtract the Lesser from the Greater; when the Northing and Westing will be found greatest, the Difference of Latitude being 155 Miles N and 79 Miles Departure West, which, compared with each other by the foregoing Rules, will give the Course and Distance as below; the Difference of Latitude reduced into Degrees is equal to $7^{\circ} 47'$.

Latitude sailed from N	45. 0	155. 5 Miles Diff. of Lat.
Difference of Lat. N	2. 35	79 Miles Departure West
Lat. come to N	47. 35	45.
Middle Parallel	46. 17	47. 35
Longitude sailed from	110. 0	
Difference of Long. W	1. 14	92. 35
Longitude come to	108. 46	
Course 27 deg. or NW 5 deg. W by		46. 17 Mid. Parallel
Dist. 174 Miles		114 Miles Diff. of Long.

MERCATOR'S SAILING.

The Use of the Meridional Line and Scale annexed upon the Blade of the Square.

In Mercator's Sailing the proper Difference of Latitude brought into Miles or Minutes, and the

the Meridional Difference of Latitude in Minutes must be considered.

The proper Difference of Latitude is the Number of Degrees and Minutes between Place and Place multiplied by 60, the Minutes in one Degree.

EXAMPLE.

If one Latitude be $40^{\circ}.00'$, the other $50^{\circ}.00'$, their Difference 10 Degrees multiplied by 60 produces 600 Miles or Minutes, the proper Difference of Latitude.

The Meridional Distance or Difference of Latitude is thus computed on these Scales upon the Square.

The Extent of a Pair of Compasses from 40 to 50 Degrees on the Meridian Line, laid from the Beginning of the Scale, gives 750 the Meridional Minutes to be used in Mercator's Way instead of 600 used in Plain Sailing.

In this there are three Varieties.

I. When one Place hath no Latitude, and the other North or South.

II. When both Places have North or South Latitude.

III. When one Place hath North, the other South Latitude.

In the first Way seek the Latitude of the North or South Place on the Meridian Line, and

and on the equal Parts right against it is the Meridional Minutes.

EXAMPLE.

I. Right against 40 Degrees on the Meridian Line in the Scale of Minutes is 2623 Minutes, which are the Meridional Minutes answering to 40 Degrees.

II. When both Places have North or South Latitude, as $45^{\circ}.00'$, and $55^{\circ}.00'$ of North or South Latitude, the Extent from 45.0° to 55.0° taken from the Meridian Line, and measured from the Beginning of the Scale of Meridional Minutes, will give the Meridional Distance or Difference in Minutes.

III. When one Latitude is North and the other South.

Extend the Compasses from the Beginning of the Meridian Line to the Lesser Latitude, and then if you apply that same Extent upon the same Line, and the same Way from the Greater Latitude, the moveable Point will (add the two Latitudes together and) fall upon the Meridional Minutes desired.

MER.

MERCATOR'S SAILING, CASE I.

*One Latitude, Course and Distance sailed given,
to find the other Latitude and Difference of
Longitude.*

EXAMPLE I.

A Ship from the Latitude of $40^{\circ}.45$, and Longitude 15.20 North, sails 180 Miles N E b N. What Difference of Longitude hath she made, and what Latitude and Longitude is she come into?

Here, as before, in Middle-Latitude Sailing, I would advise the Reader to write down, as below, every thing known or resulting from the *Data*, and to fill up the required Articles as he works the Case.

Latitude sailed from	— 40.45	150 Miles proper Diff. Lat.
Latitude come to	— 43.15	
Difference of Latitude	— 2.30	202 Merid. Diff. of Latitude
Longitude sailed from	15.20	
Difference of Longitude E	2.15	
Longitude come to	— 17.35	135 Miles Diff. of Longitude
Distance sailed	180 Miles	
Course	N E b N 3 Points	

First, set the Index to the Course which is 3 Points, and then slide the Square to the Distance 180 Miles counted on the Index, and you will have the proper Difference of Latitude 150 Miles on the Side equal to $2^{\circ}.30'$.

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which,

which, because the Course was Northerly, being added to the Latitude sailed from, will give the Latitude the Ship is in.

Then the Extent of a Pair of Compasses on the Meridian Line between the two Latitudes measured from the Beginning of the Scale of Meridional Minutes will give 202, the Meridional Difference of Latitude, to which, upon the Side, slide the Square (the Index remaining at the Course as before set) and you will have on the Square 135 Miles Ely the Difference of Longitude required equal to $2^{\circ} 15'$.

All which being wrote against their proper Articles, the Case is finished.

EXAMPLE. II.

A Ship sails from the Latitude of $50^{\circ} 30'$ N, and Longitude $359^{\circ} 6'$ S E 3 Degrees Ely or $48^{\circ} 00'$ to the Distance of 120 Miles. I demand the Difference of Longitude, the other Latitude, and Longitude come to.

Lat. sailed from N	50. 30	80 Miles proper Diff. of Lat.
Difference of Lat. S	1. 20	
Latitude come to N —	49. 10	
Longitude sailed from	359. 06	
Diff. of Long. —	2. 18	124 Miles Merid. Diff. of Lat.
Long. come to —	361. 24	138 Miles Diff. of Long.
Distance sailed 120 Miles		
Course S E 3° Ely =	48. 00	

Set the Index to the Course 48 Degrees, and slide the Square to the Distance 120 Miles counted

counted upon the Index, and, because the Angle of the Course is above 45 Degrees, you will have the proper Difference of Latitude on the Square 80 Miles (see Page 38) equal to $1^{\circ} 20'$, which, substracted from the Latitude sailed from, because the Course was Sly, will leave $49^{\circ} 10'$ the the Latitude come to.

Now, the Extent between the two Latitudes, measured from the Beginning of the Scale of Meridional Minutes, will give 124 the Meridional Difference of Latitude, which count upon the Square, (because the Angle of the Course is above $45^{\circ} 00'$) and then slide it till it intersects the Index, and you will have on the Side 138 the Difference of Longitude required equal to $2^{\circ} 18'$, which, added to the Longitude sailed from, and rejecting 360, will give $1^{\circ} 24'$ for the Longitude come to.

EXAMPLE III.

Latitude sailed from $55^{\circ} 00'$ S, and Long. $2^{\circ} 50'$, on a S W b W Course to the Distance of 600 Miles. I demand the Difference of Longitude, with the Latitude and Longitude come to.

Latitude sailed from S	55. 00	333 Miles proper Diff. of Lat.
Difference of Latitude S	5. 33	
Latitude come to S	60. 33	
Long. sailed from	— 362. 50	
Diff. of Longitude	15. 38	626 Miles Merid. Diff. of Lat.
Longitude come to	347. 12	
Distance sailed 600 Miles		938 Miles Diff. of Longitude.
Course S W b W 5 Points.		

M 2

First,

First Set the Index to the Course, which is 5 Points, and slide the Square to the Distance 600 Miles counted upon the Index, and on the Square you will have the proper Difference of Latitude 333 Miles equal to $5^{\circ} 33'$, which, being added to the Latitude sailed from, because the Course was Southerly and the Ship hath sailed farther from the Equator, will give the Latitude come to $60^{\circ} 53'$.

The Extent between the two Latitudes, measured from the Beginning of the Scale of Meridional Minutes, will give 626 the Meridional Difference of Latitude, then slide the Square till 626, or, as in this Case, its Half (for the Reason given in Case I. of Parallel Sailing) 313 intersect the Index, and you will have on the Side 469, which doubled, is 938 equal to $15^{\circ} 38'$ the Difference of Longitude required, which, being taken from the Longitude sailed from, because the Course was Westerly, will leave the Longitude the Ship is in as above.

EXAMPLE. IV.

Latitude sailed from $0^{\circ} 15'$ South, and Longitude $15^{\circ} 30'$, Distance run 160 Miles N N W, the Variation of the Compass being 10 Degrees North Westerly. What is

is the Difference of Longitude, the Latitude, and Longitude come to.

Latitude sailed from S	0. 15	135 Miles proper Diff. of Lat.
Difference of Latitude N	2. 15	
Latitude come to N	2. 00	135 Miles Merid. Diff. of Lat.
Longitude sailed from	15. 30	87 Miles Diff. of Long.
Difference in Long.	— 1. 27	
Longitude come to	— 14. 03	
Distance sailed	160 Miles	
Course NNW 2 Points		
Variation 10 Degrees NWly.		

It is here supposed that the Variation of the Needle is 10 Degrees Wly, whence it appears the Course is NNW 10° Wly; therefore, as NNW is 22°. 30', the Variation added thereto makes it 32°. 30', to which set the Index for the Course, and slide the Square to the Distance 160 Miles counted on the Index, and you will have the proper Difference of Latitude 135 on the Side equal to 2°. 15'.

As the Latitude sailed from was 0°. 15' S, and the Ship run 135 Miles Northerly, she has passed the Equator and come into 2°. 00' of North Latitude.

Therefore, in this Case, to find the Meridional Minutes, answering to this Difference of Latitude by the third Rule, Page 86, extend the Compasses from the Beginning of the Meridional Line to 0°. 15 the Lesser Latitude, and then apply that same Extent, the same Way, upon the said Line from 2°. 00' the Greater Latitude, and the moveable Point will fall on the

the Meridional Minutes at 135 for the Meridional Difference of Latitude, to which, counted on the Side, slide the Square, and you will have thereon 87 Miles Difference of Longitude equal to $1^{\circ} 27'$, which, substracted from the Longitude sailed from, leaves the Longitude come to.

MERCATOR'S SAILING, CASE II.

Both Latitudes and Course given, to find the Distance sailed, Difference of Longitude, and Longitude come to.

EXAMPLE I.

A Ship sails from the Latitude of $40^{\circ} 45'$ South, and Longitude 250° Degrees upon a Course S E b S, until she arrives in the Latitude of $43^{\circ} 15'$ South. What is her Distance and Longitude come to.

Latitude sailed from	S 40. 45	$2^{\circ} 30'$	Difference of Latitude
Latitude come to S	— 43. 15	60	
Difference of Latitude S	2. 30		
Longitude sailed from	250. 0	150	Miles proper Diff. Lat.
Difference of Longitude	2. 15		
Longitude come to	— 252. 15	202	Miles Merid. Diff. of Lat.
Distance 180 Miles		135	Miles Diff. of Long.
Course S E b S or 3 Points.			

In this Case the proper Difference of Lat. is found by substracting the Lesser Latitude from the

the Greater, which is reduced into Miles by multiplying it by 60, and is equal to 150 Miles.

The Extent between the two Latitudes, measured from the Beginning of the Scale of Meridional Minutes, will give 202 Miles the Meridional Difference of Latitude.

Then set the Index to the Course which is 3 Points, and (being under 45 Degrees) slide the Square to the proper Difference of Latitude 150 counted on the Side, and it will intersect 180 Miles the Distance on the Index.

Next remove the Square to 202 the Meridional Difference of Latitude, counted on the Side, and you will have on the Square the Difference of Longitude 135 Miles required equal to $2^{\circ}. 15'$, which, added to the Longitude sailed from, because the Course was Ely, gives the Longitude come to $252^{\circ}. 15'$.

EXAMPLE II.

Latitude sailed from $50^{\circ}. 30'$ N, and Longitude 1 Degree upon a South-East Course, when the Variation of the Compass was 3 Degrees N Wly, until the Ship was come into the Latitude of $49^{\circ}. 10'$ North. I demand the Distance

Distance run, Difference of Longitude, and Longitude come to.

Latitude sailed from N	50. 30	1. 20	Diff. Lat.
Lat. come to N	49. 10	60	
Difference of Lat. S	1. 20		
Longitude sailed from	1. 00	80	Miles proper Diff. Lat.
Difference of Longitude	2. 18	188	Miles Merid. Diff. Lat.
Longitude come to	3. 18	138	Difference of Long.
Distance sailed	120 Miles		
Course S E 3 Deg. Ely, or 48°.00			

In this Example the Variation of the Compass is supposed to be from the N 3 Degrees Wly; therefore as the Course steered S E, or 45°.00', the Variation 3 Degrees must be added thereto, which will make it 48 Degrees for the true Course; because, as the Variation was N Wly, all the Western Points of the Compass decline towards the South, and all the Eastern Points towards the North. See *Example II. of Case II, of Middle Lat. Sailing.*

Now place the Index to 48 Degrees the true Course, and and slide the Square till the proper Difference of Latitude 80 counted on the Square (because the Angle is above 45°) intersect the Index, and you will have on the Index 120 Miles for the Distance.

Then the Extent between the Latitudes will give 126 Meridional Parts or Minutes, which count on the Square, and then slide it to intersect the Index, and you will have on the Side 138 Miles for the required Difference of Longitude equal to 2°.18', which
being

being added to the Longitude sailed from gives 3, 18 the Longitude the Ship is in.

EXAMPLE III.

A Ship sails from the Latitude of $0^{\circ}.15'$ South, and Longitude 110 Degrees, upon a Course NNW 10 Degrees W , or $32^{\circ}.30'$, until she comes into 2 Degrees of North Latitude. I demand her Distance, Difference of Longitude, and Longitude come to.

Lat. sailed from S.	0. 15	2. 15
Latitude come to N	2. 00	60
Diff. of Latitude N	2. 15	
Longitude sailed from	110. 00	135 Miles proper Diff. Lat.
Longitude come to	108. 33	
Difference in Long. W	1. 27	135 Miles Merid. Diff. Lat.
Distance	160	
Course NW 10 W, or $30^{\circ}.30'$		87 Miles Diff. of Longitude

Set the Index to $32^{\circ}.30'$ the Course, and because the Angle is under $45^{\circ}.00'$, slide the Square to 135 the proper Difference of Latitude counted upon the Side, and you will have on the Index 160 Miles for the Distance.

Then the Extent between the two Latitudes will give 135 Miles the Meridional Difference of Latitude, which being the same as the proper Difference of Latitude from its Nearness to the Equator, therefore the Square need not be removed, but will give the Difference of Longitude on the Square 87 Miles equal to $1^{\circ}.19'$, &c. &c.

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N. B.

N. B. As the two Latitudes were of different Denominations, they were added together to give their Difference, which, in this Case, is really the Interval between them, or their Change, having crossed the Equator.

MERCATOR'S SAILING, CASE III.

One Latitude, Course and Departure given to find the other Latitude, Distance and Difference of Longitude, with the Longitude come to.

EXAMPLE.

A Ship at Sea in the Latitude of $48^{\circ} 23' N$, and Difference of Longitude 323 Degrees, sails S W b S, until her Departure be 123 Miles. What is her Latitude come to, Difference of Longitude, and Distance sailed.

Latitude sailed from —	48. 23	123 Miles Departure West
Lat. come to —	45. 19	184 Miles proper Diff. of Lat.
Difference of Lat. —	3. 04	
Longitude sailed from —	323. 00	270 Miles Merid. Diff. of Lat.
Difference of Long. —	3. 00	180 Miles Diff. of Long.
Longitude come to —	320. 00	
Dist. sailed —	123	
Course S W b S	3 Points.	

Set the Index to the Course which is 3 Points, and because the Angle thereof is under 45 Degrees, count the Departure 123 on the Square, which slide to intersect the Index, and you will have thereon 221 for the Distance, and

184 on the Side for the proper Difference of Latitude equal to $3^{\circ}.04'$, which being subtracted from the Latitude sailed from, will give the Latitude come to $45^{\circ}.19'$.

Now, having both Latitudes, to find the Meridional Difference of Latitude by taking the Extent between them, on the Meridian Line, and measuring it on the Meridional Minutes, which will give 270 Miles the Meridional Difference of Latitude, then remove the Square to 270 upon the Side, and you will have on the Square 180 Miles for the Difference of Longitude equal to $30^{\circ}.00'$, which taken from the Longitude sailed from, leaves the Longitude come to $320^{\circ}.00'$.

MERCATOR'S SHILING, CASE IV.

Both Latitudes and Distance given, to find the Course, Departure, Difference of Longitude, and Longitude come to.

EXAMPLE.

A Ship sails from the Latitude of $50^{\circ}.30'$ North. and Longitude $35^{\circ}.10'$, to the Distance of 135 Miles, between the South and East, until, by Observation, she is found in

N 2

the

EXAMPLE II.

the Latitude of $49^{\circ}.00'$ North. I demand
her direct Course, Difference of Longitude,
Ec. Ec.

Latitude sailed from N	50. 30	90 Miles proper Diff. of Lat.
Latitude come to N	— 49. 0	100 Miles Departure
Difference of Latitude S	1. 30	
Longitude sailed from	35. 10	140 Miles Merid. Diff. of Lat.
Longitude come to	— 2. 36	
Difference of Long.	— 37. 46	156 Miles Diff. of Long.
Distance sailed	135 Miles	
Course	$48^{\circ}.00'$ or SE 3.10 Ely	

Find the Difference of Latitude by subtracting the Lesser from the Greater, which, reduced into Miles, is 90 the proper Difference of Latitude.

Then slide the Square and move the Index until 90 Miles the proper Difference of Latitude counted on the Square intersect 135 Miles the Distance counted on the Index, and you will have the Course $48^{\circ}.10'$ on the Arch, and on the Side you will have 100 Miles for the Departure.

The Extent between the two Latitudes on the Meridian Line measured, on the Scale of Minutes, will give 140; therefore slide the Square till 140 counted thereon Intersect the Index, and you will have on the Side the Difference of Longitude 156 equal to $2^{\circ}.36'$, which, added to the Longitude sailed from, gives the Longitude come to, 37. 46.

EXAMPLE II.

EXAMPLE II.

Latitude sailed from $48^{\circ} 45' N$, Longitude 2. 50, Distance run 480 Miles between the South and West, Latitude come to by Observation $43. 30 N$. Required the Course, Difference of Longitude, &c.

Latitude sailed from N	48. 45	5. 15	Difference of Latitude
Latitude come to N	— 43. 30	60	
Difference of Latitude	5. 15		
Longitude sailed from	362. 50	315	Miles proper Diff. Lat.
Difference of Long. Wly	8. 42		
Longitude come to	— 354. 08	454	Merid. Diff. of Lat.
Distance sailed	480 Miles	522	Miles Diff. of Long.
Course	$49^{\circ}.00$, or S W 4 Wly.		

MERCATOR'S SAILING, CASE V.

One Latitude, Distance and Departure given, to find the other Latitude, Course, Difference of Longitude, and Longitude come to.

EXAMPLE.

A Ship sails from the Latitude of $50^{\circ}. 00' N$, and Longitude $165^{\circ}. 00'$, between the South and West 150 Miles, until her Departure be 115 Miles, What is the other Latitude, Course,

Course, Difference of Longitude, and Longitude come to.

II. EXAMPLE.

Latitude sailed from N	50. 00	115 Miles Departure
Latitude come to N	48. 24	96. 1 Miles proper Diff. of Lat.
Difference of Latitude S	1. 36	
Long. sailed from	165. 00	146 Merid. Diff. of Lat.
Longitude come to	162. 05	175 Miles Diff. of Longitude
Diff. of Longitude	2. 55	
Distance sailed	150 Miles	
Course S	50. 07 Wly	

Slide the Square to 115 Miles Departure counted upon the Side, and move the Index untill 150 Miles counted thereon intersect the Square, and you will have the Course $50^{\circ}.07'$ on the Arch, and the proper Difference of Latitude on the Square 96. 1, equal to $1^{\circ}.36'$, which being deducted from the Latitude sailed from, will leave $48^{\circ}.24'$ the Latitude come to.

Then the Extent upon the Meridian Line between the two Latitudes applied to the Beginning of the Scale of Meridional Minutes will give 146, which Number counted upon the Square slide till it intersects the Index, and on the Side you will have the Difference of Longitude required 175.

EXAMPLE. II.

A Ship at Sea sails from the Latitude of $45^{\circ}.40'$ North, between the South and East 600 Miles, when her Departure was computed

puted at 308 Miles. Required the Latitude the Ship is in, the Course and Difference of Longitude.

Latitude sailed from	N 45. 40	308 Miles Departure
Latitude come to	— 37. 06	514 Miles proper Diff. Lat.
Difference of Latitude	— 8. 34	
Longitude sailed from	258. 10	688 Merid. Diff. of Latitude
Longitude come to	— 250. 0	
Difference of Longitude	8. 12	412 Miles Diff. of Longitude
Dist. sailed	600 Miles	
Course	S 30. 53 Ely	

Slide the Index and Square until 600 Miles the Distance counted on the Index cuts 308 the Departure counted on the Square, and on the Arch you will have the Course 30°. 53, which is S 30. 53 Ely. or SSE $\frac{1}{4}$ Ely; at the same time you will have on the Side the proper Difference of Latitude 514 equal to 8. 34, which, because the Ship sailed Southerly, and by that Means lessened her Latitude, being substracted from the 45. 40, gives 37. 06 the Latitude the Ship is in; then taking the Extent between the two Latitudes from the Meridian Line and applying it to the Beginning of the Scale of Minutes, you will have 688 for the Meridional Difference of Latitude, to which, upon the Side, set the Square, and you will have thereon 412 equal to 8°. 12 Wly the Difference of Longitude required.

MERCATOR'S SAILING, CASE VI.

Both Latitudes and Departure given, to find the Course, Distance, Difference of Longitude, and Longitude come to.

EXAMPLE.

A Ship sails from the Latitude of $40^{\circ} 45' N$, and Longitude $354. 0$, between the North and East, till she has made her Departure 100 Miles Ely, and is then found in the Latitude of $43^{\circ} 15'$ by Observation. Required the Course, Distance, and Difference of Longitude.

Latitude sailed from N	40. 45	2. 30	
Lat. come to N	43. 15	60	
Difference of Lat. N	2. 30		
Longitude sailed from	354. 0	150	Miles proper Diff. Lat.
Longitude come to	356. 15		
Difference of Longitude	2. 15	100	Miles Departure
Distance	180	202	Merid. Diff. Lat.
Course $33^{\circ} 40'$, or NE $\frac{1}{2}$ N		135	Difference of Long.

Slide the Square to 150 the proper Difference of Latitude counted upon the Side, and then move the Index till it intersect 100 Miles the Departure counted on the Square, and you will have the Distance 180 on the Index, and the Course $33^{\circ} 40'$ on the Arch.

Next the Extent between the two Latitudes applied to the Scale of Minutes will give 209 the

the Meridional Difference of Latitude, to which, counted on the Side, slide the Square, and you will have on the Square 135 the Difference of Longitude required equal to 2. 15, which, added to the Longitude sailed from, gives the Longitude come to.

MERCATOR'S SAILING, CASE VII.

Both Latitudes and Difference of Longitude given, to find the Course and Distance.

EXAMPLE I.

A Ship sails from the Latitude of $40^{\circ}.45'$ N, and Longitude $354^{\circ}.00'$, between the North and East, until she is found in the Latitude of 43.15 , and Longitude 356.15 . I demand the Course and Distance.

Lat. sailed from N	40. 45	150 Miles proper Diff. of Lat.
Latitude come to N —	43. 15	
Difference of Lat. N	2. 30	135 Miles Diff. Long. equal 2. 15
Longitude sailed from	354. 00	
Diff. of Long. —	2. 15	
Long. come to —	356. 15	202 Miles Merid. Diff. of Lat.
Distance sailed	180 Miles	
Course	33. 40, or N E b N nearly	

The Difference of Latitude is had by subtracting one from the other: So also is the Difference of Longitude, which is Ely, because the Longitude come to is greater than the other.

O

First,

First, the Extent between the two Latitudes, measured on the Beginning of the Scale of Minutes, will give 202 for the Meridional Difference of Latitude.

Then set the Square to 202, the Meridional Difference of Latitude counted upon the Side, and move the Index till it intersect 135 the Difference of Longitude counted on the Square, and then on the Arch you will have the Course $33^{\circ}.40'$.

Next, the Index remaining, slide the Square to the proper Difference of Latitude 150 counted upon the Side, and you will have on the Index 180 Miles for the Distance required.

EXAMPLE II.

A Ship sails from the Latitude $58^{\circ}.45' N$, and Longitude $7^{\circ}.30'$, into Latitude $52^{\circ}.30' N$, and Longitude 354.14 . Required the Course and Distance.

Latitude sailed from N 58.45	6. 15	
Latitude come to N — 52.30	60	
Difference of Latitude S 6.15		
Longitude sailed from 367.30	375	Miles proper Diff. Lat.
Longitude come to — 354.54		
Difference of Long. Wly 12.36	668	Merid. Diff. of Lat.
Distance sailed 567 Miles		
Course S W 3.40 Wly.	12. 36	
	60	
	756	Miles Diff. of Long.

In this Example the Difference of Latitude is Southerly, because the Latitude is lessened.

Instead

Instead of writing down $7^{\circ}.30'$ for the Longitude sailed from, I have put 367. 30. It was necessary to make this Augmentation in order to come at the Difference of Longitude in the shortest Way, which is West, because the Longitude is decreased.

After having found the Proper and Meridional Difference of Latitude, as before directed.

Set the Square to 756 Miles the Difference of Longitude counted on the Side, and slide the Index until it intersect 668 the Meridional Difference of Latitude, and on the Arch you will have $48^{\circ}.40'$ for the Course, which, because the Ship sailed from the North Westerly, is S W $3^{\circ}.40'$ W.

Then slide the Square till the proper Difference of Latitude counted thereon intersect the Index, and you will have on the Index the Distance 167 required.

We learn from this Example, that to sail from one of these Points to the other it ought to be S W $3^{\circ}.40'$ W, but if there should be any Variation in the Compass, it must be observed.

Suppose the Variation was N Wly 4 Degrees, all the Points of the Compass on the West Side would tend just so much toward the South; so that in steering S W $3^{\circ}.40'$ Wly, the Ship would not run so near the West as it ought; therefore we must take S W $7^{\circ}.40'$ Wly upon the Compass Card for the true Course to steer upon.

EXAMPLE III.

A Ship sails from the Latitude of $5^{\circ}.01\text{ S}$, and Longitude $357^{\circ}.0'$, into $7^{\circ}.00'$ of North Latitude, and $8^{\circ}.00'$ of Longitude. I demand the Course and Distance.

<i>Lat. sailed from S.</i>	5. 00	12	
<i>Latitude come to N —</i>	7. 00	60	
<i>Diff. of Latitude —</i>	12. 00		
<i>Longitude sailed from</i>	357. 0	720	<i>Miles proper Diff. Lat.</i>
<i>Longitude come to</i>	368. 0		
<i>Difference of Long.</i>	11. 0	722	<i>Miles Merid. Diff. Lat.</i>
<i>Distance</i>	978		
<i>Course</i>	42. 26	11	
		62	
			660 Miles Diff. of Long. Ely

In this Example the two Latitudes are added together to find their Difference, because one is North and the other South, having crossed the Equator and sailed Northward. The Difference of Longitude is Ely, because the Longitude is encreased, for 8 Degrees is the same Thing as 368, which is greater than 357 Degrees, the 11 Degrees Difference of Longitude is equal to 660 Miles.

In order to find the Meridional Difference of Latitude by Rule III. in Page 86 extend the Compasses from the Beginning of the Meridian Line to $5^{\circ}.00'$ the Lesser Latitude, and then apply that same Extent the same Way upon the same Line from the greater Latitude, and the moveable

moveable Point will fall upon 722 the Meridional Minutes required.

Now set the Square to 722 on the Side, and move the Index till it intersect 660 the Difference of Longitude counted upon the Square, and you will have on the Arch $42^{\circ}. 30'$ for the Course.

Next for the Distance: The Index remaining as before, slide the Square to 720 the proper Difference of Latitude counted on the Side, and you will have 978 Miles on the Index, the Distance required.

MERCATOR'S SAILING, CASE VIII.

Given one Latitude, Course and Difference of Longitude, to find the other Latitude, Distance and Départure.

EXAMPLE..

A Ship sails from the Latitude $45. 20$ N, and Longitude 323 Degrees, upon a Course NE 3 Degrees E, into the Longitude of $345^{\circ}. 36'$. I demand the other Latitude, Distance and Départure.

Latitude

<i>Latitude sailed from</i> N 45. 20	22. 36 60
<i>Latitude come to</i> N — 57. 50	1356 <i>Miles Diff. of Longitude</i>
<i>Difference of Latitude</i> — 12. 30	678 <i>the Half of ditto</i>
<i>Longitude sailed from</i> 323. 0	<i>Meridional Parts</i> 3058 45°. 20'
<i>Longitude come to</i> — 345. 36	1218 <i>Merid. Diff. of Latitude</i> 4276 47. 50
<i>Difference of Longitude</i> E 22. 36	12. 30 60
<i>Dist.</i> 1122	750 <i>proper Diff. Lat.</i>
<i>Course</i> 48°. N E 3° E	375 <i>its Half</i> 836 <i>the Departure</i>

Set the Index to the Course 48°. 00', and count 678 the half of the Difference of Longitude upon the Side, whereunto slide the Square, and on the Square you will have 609, the Double of which 1218 is the Difference of Latitude in Meridional Parts, which, added to the Meridional Parts against 45°. 20', will give 4276, against which counted on the Scale of Meridional Minutes is 57°. 50 the Latitude the Ship is in.

The required Latitude may be obtained something easier, if the Extent be not too long for your Compasses, by taking the Extent 1218 from the Beginning of the Scale of Minutes, and setting one Foot of your Compasses in the given Latitude, turn the moveable Point upwards, because the Ship sailed from the Equator, and

and it will fall on $57^{\circ}.50'$ the Latitude required.

Then set the half of the proper Difference of Latitude 375 counted on the Square to intersect the Index, and you will have on the Index 561, the double whereof, 1122, is the Distance required, and on the Side you will have 418, whose double is 836 Miles the Dep.

Of a TRAVERSE, or COMPOUND COURSE.

When the Distances are but small, it is sufficient only to find the Difference of Latitude and Departure corresponding to each single Course, and from thence the Difference of Latitude and Departure made good; by which the true Place of the Ship may be found.

EXAMPLE.

A Ship from the Latitude of $40^{\circ}.00' N$, and Longitude $12^{\circ}.15'$ sails the following Courses and Distances, I demand the direct Course, Distance and Latitude come to.

Courses	Pts.	Dist.	Diff. Lat.		Departure.	
			N	S	E	W
NE	4	30	21.2		21.2	
NNW	2	55	60.0			24.9
ESE	6	27		10.3	25.0	
WbN	7	86	16.7			84.5
NW	4	70	49.6			49.6
			147.5	10.3	46.2	158.9
			10.3			46.2
Diff. Lat. 137.2					Dep. 112.7	

By

By the first Case of Plain Sailing find the Difference of Latitude and Departure for each Course and Distance, which enter in their proper Columns, as before directed, in Page 50. Then, for the first Course, being four Points, set the Index to 4 Points upon the Arch, and slide the Square to the Distance counted upon the Index, and you will have the Difference of Latitude 21. 2 on the Side, and the Departure 21. 2 on the Index. For the second Course, 2 Points, set the Index thereto, and slide the Square to the Distance 65, and on the Side you will have the Difference of Latitude 60. 0, and on the Square 24. 9 the Departure. In the same Manner all the other Courses are to be worked upon the Universal Octant, and set down in the Traverse Table as above.

The Difference of Latitude and Departure being thus found and disposed of, as in the foregoing Table, the Totals shew, that as the Northings exceed the Southings, the Ship has sailed Northerly 137. 2 Miles equal to $2^{\circ}. 17'$.

Therefore, to the Latitude sailed from, add the Difference of Latitude made, the Sum is the Latitude the Ship is in, as below.

And, also, because the Sum of the Westings exceed the Sum of the Eastings by 112.7 Miles, the Departure is so much Westerly; then find the direct Course and Distance, &c. and then
by

by Case VI. of Mercator's Sailing, you have both Latitudes and Departure, to find the Course, Distance and Difference of Longitude.

Latitude sailed from	40. 00	137.2 Miles proper Diff. of Lat.
Difference of Latitude	2. 17	
Latitude come to	42. 17	112.6 Miles Departure
Longitude sailed from	12. 15	
Difference of Long.	2. 38	
Longitude come to	9. 37	182 Miles Merid. Diff. of Lat.
Distance sailed	178	
Course 2 Points N W b N $\frac{1}{2}$ Wly		158 Miles Diff. of Long.

Set the Square to 137.2 the proper Difference of Latitude counted upon the Side, and then move the Index till it intersect 112.6 Miles the Departure counted upon the Square, and you will have the Course $3. \frac{1}{2}$ Points upon the Arch, which, because it was between the N and W, is N W b N $\frac{1}{2}$ Wly, and Distance on the Index 178.

Then the Extent between the two Latitudes, applied to the Scale of Minutes, will give 182 the Meridional Difference of Latitude, to which, counted on the Side, slide the Square, and on the Square you will have 158 the Difference of Longitude equal to $2^{\circ}. 38'$, which, because the Ship sailed Westerly, being taken from the Longitude sailed from, gives the Longitude of the Place the Ship is in.

When the Distances run are pretty large, instead of finding the Difference of Latitude and Departure, the Difference of Longitude corresponding with each Course ought to be found.

P

EXAMPLE.

EXAMPLE.

Suppose a Ship, from the Latitude of $50^{\circ} 00' N$, and Longitude $5^{\circ} 05' E$, is bound to a Port, in the Latitude of $28^{\circ} 15' N$, and Longitude $340^{\circ} 50'$, and after having made the proper Allowances for Variation, Lee-Way, Currents, &c. has sailed upon the following corrected Courses. I demand the Latitude come to, the Bearing, and Distance from the Ship to her desired Port.

No	Courses.	Points.	Distances.	Difference of Lat.		Latitude come to.	Merid. Min.	Diff. of Long.	
				N	S	D. M.		E	W
1	Sb W	1	420		412	6.52	43.8	600	118
2	W	8	156			6.52	43.8		215
3	SSW	2	250		231	3.51	39.17	306	128
4	SW	4	197		139	2.19	36.58	178	178
5	SEbS	3	300		249	4.9	32.49	304	203
6	NWbW	5	322	178		2.58	35.47	216	324
7	WbN	7	180	135		0.35	36.22	43	168
8	S	0	185		185	3.5	33.17	225	
9	WSW	6	100		38.3	0.38	32.39	45	
				213	1254.3			203	1351
					213.0				203

Diff. Lat. 1041.3

Diff. Long. 1148

First find the Differences of Latitude, by setting the Index to the Angle of each Course upon the Arch, and then slide the Square to each respective Distance counted upon the Index, and if the Angle of the the Course be under $45^{\circ}.00$, you will have the Difference of Latitude on the Side; but if the said Angle of the Course be above 45, then the Difference of Latitude must be counted on the Square.

Having thus found the Differences of Latitude in Miles for each respective Course, and placed them in their proper Columns, either N or S, as the Course directs, reduce each of them into Degrees and Minutes, by dividing them by 60, and write them down in the Column under Difference of Latitude in Degrees and Minutes.

N. B. This Division may be performed without making any more Figures than what ought to stand in the above Table, viz by making a Dash over the last Figure in whole Numbers towards the Right Hand, and dividing the Left Hand Figures by 6, and the Remainder will be Minutes.

EXAMPLE.

In the first Course S b W the Difference of Longitude is $41\frac{1}{2}$ Miles; I put a Dash between the two last Right Hand Figures, which cuts off the Figure 2, then divide 41 the Figures to the Left Hand by 6, which is 6 Times and 5

P 2

over

over; therefore I write down in the next Column 6 Degees under D, and the 5 Remainder, being 5 Tens, added to the Figure cut off, makes 52; and so of all the rest.

By the Rules already laid down. the Difference of Latitude, reduced into Minutes, being either added to, or subtracted from the Latitude come to, in each preceding Course, as the former Rules have directed, will give the Latitude the Ship was in at the next succeeding Course, as in the above Table.

Then for the Difference of Longitude to every Course, observe the following Rules.

For the first Course S b W. Set the Index to 1 Point upon the Arch, and take the Extent from $50^{\circ}.00'$ (the Latitude sailed from) upon the Meridian Line to the Latitude made upon this first Course $43^{\circ}.08'$, which, measured from the Beginning of the Scale of Meridional Minutes, will give 600, to which, counted on the Side, apply the Square, and you will have on the Square 118 the Difference of Longitude to be set in the West Column.

. Observe, when the Angle of the Course is under 45 Degrees, count the Meridional Minutes on the Side, and you will have the Difference of Longitude on the Square; but if the Angle of the Course is above 45 Degrees, then count the Meridional Minutes upon the Square, and you will have the Difference of Longitude

Longitude on the Side. Remember this once for all.

For the second Course, being full West, and Distance 156, the Ship did not alter her Latitude; so that the Rule for finding the Longitude by the Difference of Latitude and Meridional Minutes cannot be used in this Case, there being no Difference of Latitude; we must therefore have Recourse to Case I. of Parallel Sailing, to find the Difference of Longitude upon an E or W Course.

Therefore set the Index to the Latitude $43^{\circ}.08'$, and slide the Square to the Distance sailed 156 Miles counted on the Side, and you will have the Difference of Longitude 215 upon the Index to be set in the West Column.

* * Here also observe, when the Difference of Longitude is required upon any Parallel of Latitude, and the Angle of Latitude is under 45 Degrees, to count the Distance run upon the Side, and if it be above 45 Degrees, to count it upon the Square, and in either Case you will have the Difference of Longitude on the Index.

The 3d Course S S W. Set the Index to 2 Points, and the Extent between the Latitude $43^{\circ}.08'$ and $39^{\circ}.17'$ upon the Scale of Minutes, will give 306, to which, on the Side, apply the Square, and you will have on the the Square 128 the Difference of Longitude, to be set in the West Column.

The

The 4th Course S W. Set the Index to 4 Points, and measure the Extent between $39^{\circ}.17'$ and $36^{\circ}.58'$, which will be 178, to which, on the Side, set the Square, and you will have on the Index the Difference of Longitude 178 to be set in the West Column.

* * When the Angle is 45 Degrees, the Meridional Minutes and Difference of Longitude is equal; therefore it is indifferent whether you count the Minutes on the Square or on the Index; for, in such a Case, the Operation might be saved, and the Meridional Minutes set down for Difference of Longitude, they being both the same.

The 5th Course S E b S. Set the Index to 3 Points, and take the Extent between Latitude $36^{\circ}.58'$ and $32^{\circ}.49'$, which will give on the Minute Scale 304, to which, on the Side, set the Square, and you will have on the Square 203 the Difference of Longitude to be set in the East Column.

The 6th Course N W b W. Set the Index to 5 Points, and measure the Extent between Latitude $32^{\circ}.49'$ and 35° , which is 216, and then slide the Square till that Number counted on the Square intersect the Index, and you will have 324 the Difference of Longitude on the Side to be put in the West Column.

The 7th Course W b N. Set the Index to 7 Points, and then take the Extent between $35^{\circ}.47'$ to $36^{\circ}.22'$, which upon the Scale of Minutes is 43, the Square being slid till the

the Index intersect that Number counted upon the Square, and you will have on the Side 168 the Difference of Longitude to be set in the West Column.

The 8th Course being full South has no Difference of Longitude, therefore the East and West Columns are left blank.

The 9th Course W S W, Set the Index to 6 Points, and measure the Extent between the Latitudes of $33^{\circ}.17'$ and $32^{\circ}.39'$, which is 45, count this upon the Square and you will have upon the Side 220, the Difference of Longitude to be set in the West Column.

Thus you will find by the Latitude opposite to the last Course that the Ship is come into Latitude $32^{\circ}.39' N$, and that she has made 1148 Miles equal to $19^{\circ}.08'$ Difference of Longitude Wly.

Whence we shall have both Latitudes and Difference of Longitude, to find the direct Course, Distance and Departure by Case VII. of Mercator's Sailing, which state as follows.

Latitude sailed from N	50. 00	17. 21 Diff. of Lat.
Latitude come to N	32. 39	60
Difference of Latitude	17. 21	—
Long. sailed from E	365. 05	1041 pro. Diff. of Lat. in Miles
Diff. of Longitude W	19. 08	1400 Merid. Diff. of Lat.
Longitude come to W	345. 57	1148 Miles Diff. of Longitude.
Distance sailed	1398 Miles	
Course	39.14 or nearly $SWbS\frac{1}{2}Wly$	822 Departure

The

The Extent between the two Latitudes 50° , 80° , and 32.39 upon the Meridional Line will give 1400 the Meridional Difference of Latitude.

Then set the Square to 700, the Half of 1400 the Meridional Difference of Latitude counted upon the Side, and move the Index untill it intersect 572 the Half of 1148 the Difference of Longitude counted on the Square and on the Arch you will have the Course $39^{\circ}.14'$, which is nearly $SW \text{ by } S \frac{1}{2} W$.

Next slide the Square to 520. $\frac{1}{2}$ the Half of 1041 counted upon the Side, and you will have on the Index 649, the double of which is 1298 the Distance sailed, and on the Square 411, the double of which is 822 Miles the Departure.

Now to find the Bearing and Distance from the Ship to her desired Port.

From the Latitude the Ship is in N 32. 39
Subtract the Latitude bound to N 28. 15

Remain the Diff. of Lat. 4. 24
60

Proper Diff. of Lat. Miles 264

Again,

From the Longitude come to 345. 57
Take the Longitude bound to 340. 50

Remains the Diff. of Long. 5. 07
60

Between the Ship and her intended Port equal to Miles 307

Here

Here again, as before, we have both Latitudes and Difference of Longitude, to find the Course and Distance.

Therefore the Extent between the two Latitudes $32^{\circ}.39'$ and $28^{\circ}.15'$, upon the Meridian Line, will give upon the Scale of Meridional Minutes 207 for the Meridional Difference of Latitude.

Then set the Square to the Difference of Longitude 307 counted upon the Side, and move the Index till it intersect the Meridional Difference of Latitude 207 counted on the Square, and you will have on the Arch $56^{\circ}.05'$ for the Course nearly S W b W; next remove the Square to 520 the Half of the proper Difference of Latitude 1041 counted on the Square, and it will cut on the Index 932 Miles, the required Distance from the Ship to the Port bound to.

As these last Examples are in constant Practice at Sea, as well for working the Day's Work, as keeping a Journal thereby, and also for finding the Course and Distance between Place and Place, or to find the Bearing and Distance at any time, I have set down every Part of the Work at large to perfect the Reader therein.

Lat	Long	Course	Distance
32.39	104.1	56.05	932
28.15	307		
207			
520			

((120))

A Table of the Angles in Degrees and Minutes which every $\frac{1}{4}$ Point of the Compass makes with the Meridian.

N	S	Pts.	0	1	S	N
		$\frac{1}{4}$	2. 48	$\frac{3}{4}$		
		$\frac{1}{2}$	5. 37	$\frac{1}{2}$		
		$\frac{3}{4}$	8. 26	$\frac{1}{4}$		
N b E	S b E	1 0	11. 15		S b W	N b W
		$\frac{1}{4}$	14. 03	$\frac{3}{4}$		
		$\frac{1}{2}$	16. 52	$\frac{1}{2}$		
		$\frac{3}{4}$	19. 41	$\frac{1}{4}$		
N N E	S S E	2 0	22. 30		S S W	N N W
		$\frac{1}{4}$	25. 18	$\frac{3}{4}$		
		$\frac{1}{2}$	28. 07	$\frac{1}{2}$		
		$\frac{3}{4}$	30. 56	$\frac{1}{4}$		
N E b N	S E b S	3 0	33. 15		S W b S	N W b N
		$\frac{1}{4}$	36. 33	$\frac{3}{4}$		
		$\frac{1}{2}$	39. 22	$\frac{1}{2}$		
		$\frac{3}{4}$	42. 11	$\frac{1}{4}$		
N E	S E	4 0	45. 00		S W	N W
		$\frac{1}{4}$	47. 48	$\frac{3}{4}$		
		$\frac{1}{2}$	50. 37	$\frac{1}{2}$		
		$\frac{3}{4}$	53. 26	$\frac{1}{4}$		
N E b E	S E b E	5 0	56. 15		S W b W	N W b W
		$\frac{1}{4}$	59. 03	$\frac{3}{4}$		
		$\frac{1}{2}$	61. 52	$\frac{1}{2}$		
		$\frac{3}{4}$	64. 41	$\frac{1}{4}$		
N E	S E	6 0	67. 30		S W	N W
		$\frac{1}{4}$	70. 18	$\frac{3}{4}$		
		$\frac{1}{2}$	73. 07	$\frac{1}{2}$		
		$\frac{3}{4}$	75. 56	$\frac{1}{4}$		
E b N	E b S	7 0	78. 45		W b S	W b N
		$\frac{1}{4}$	81. 33	$\frac{3}{4}$		
		$\frac{1}{2}$	84. 22	$\frac{1}{2}$		
		$\frac{3}{4}$	87. 11	$\frac{1}{4}$		
		8 0	90. 00			
East.						West.

This

The Use of this Table is to turn Points into Degrees and Degrees into Points. Example. How many Degrees is 5 Points? Look for 5 Points, and over-against it is $56^{\circ} 15'$. Example 2. How many Points is $75^{\circ} 57'$? Look for the nearest to it which is $75^{\circ} 56'$, and against that you will find 6 Points and $\frac{1}{4}$.

The following Astronomical Problems being of general Use in the Practice of Navigation, are here inserted, that the Variation of the Compass-Needle, the Sun's rising, setting, Amplitude, Azimuth, and Hour of the Day, &c. in any Latitude, might be at any time attained by The Universal Octant, without the Assistance of the Logarithmic Tables.

PROBLEM I.

To find the Right Sine of any given Arch by the Universal Octant. The Radius being 1000.

Set the Index to the Degree given upon the Arch, and slide the Square to 100 upon the Index, and if the Angle be under forty-five Degrees, you will have the natural Number for the Sine upon the Square, if above 45° Degrees upon the Side. Note, also, that when the Square gives the Sine, the Side gives the Cosine; and, contrarily, when the Side gives the Sine, the Square gives the Cosine.

Q 2

EXAMPLE I.

EXAMPLE..

What is the Right Sine of 25 Degrees? Set the Index to 25 Degrees upon the Arch, and slide the Square to 100 upon the Index, and, because it is less than 45. 00, you will have on the Square 422, the Right Sine of 25 Degrees, 1000 being Radius.

EXAMPLE II.

What is the Right Sine of $53^{\circ}.45'$? Set the Index to $53^{\circ}.45'$ on the Arch, and slide the Square to 100 on the Index, and, because the Angle is greater than $45^{\circ}.00'$, you will have 807, the Right Sine of 53.45 .

PROBLEM II.

To find the Arch of any given Sine.

If the Sine given is less than 707, or exceeds 707, which is the Right Sine of 45 Degrees, in the first Case move the Index and Square until 100 on the Index cut the given Number counted upon the Square, and you will have the Degrees and Minutes under $45^{\circ}.00'$ answering thereto upon the Arch: in the second Case, slide the Square to the given Number counted upon the Side, and move the Index

until

untill 100 intersect the Square, and you will have on the Arch the Degrees and Minutes above $45^{\circ}.00'$ to the given Sine.

EXAMPLE I.

Let 480 be the given Sine. I would know the Arch corresponding thereto.

The given Number being less than 707, slide the Square and Index untill 100 on the Index cut 480 on the Square, and you will have on the Arch $28^{\circ}.42'$ the required Angle.

EXAMPLE II.

Let 930 be the given Sine, to find the Arch corresponding thereto.

As this Number is above 707, set the Square to 930 counted upon the Side, and move the Index till 100 is cut by the Edge of the Square, and you will have on the Arch $68^{\circ}.27'$ for the Angle required.

PROBLEM III.

The Latitude and Sun's Declination given, to find his Height in the Prime Vertical, or when he is due East or West.

EXAMPLE.

until 100 intersect the Square, and you will have on the Arch the Degrees and Minutes above 45.00 to the given Line.

EXAMPLE.

The Latitude 51. 30 N, its Sine 783.
Sun's Declination 19. 38 N, its Sine 336.

Count 783 the Sine of the Latitude upon the Index, and to it apply 336 the Sine of the Declination counted upon the Square, and you will have on the Arch 25. the Sun's Height when it is upon the Prime Vertical.

If the Declination be the same as the Latitude, then it shews the Sun's Depression, at the time he is below the Horizon, and upon the Vertical Circle.

PROBLEM IV.

The Latitude and Sun's Declination given, to find the Time when he will be due East and West.

The Latitude 51. 30 N—Sine 783—Cofine 622.
Sun's Declin. 19. 38 N—Sine 336—Cofine 942

First, by Problem I. find the Sine and Cofine of the Latitude and Declination, which write down as above, then count the Sine of the Latitude 783 upon the Index, to which apply 336 the Sine of the Declination counted upon the Square, and letting the Index remain, slide the Square to the Cofine of the Latitude 622 counted upon the Index, and you will have on the

the Square 267. Now compare this last Number with 942 the Cofine of the Declination counted upon the Index, and you will have on the Arch $16^{\circ}.29'$ the Quantity of Time from the Hour of Six, and the Sun's being in the East and West Points.

To convert this into Time allow 15 Degrees to an Hour, and 15 Minutes of a Degree to a Minute of Time.

	Ho.	Min.	Sec.
Then to 90 Degrees or	6	0	0
Add the Time last found	1	5	56
The Sum is the Time when the Sun is due East in the Morning	7	5	56

Or,

	Ho.	Min.	Sec.
From 90 Degrees or	6	0	0
Subtract the Time last found	1	5	56
Remains the Time when the Sun is due West in the Afternoon	4	54	4

The Sun's Declination and Latitude in this Example are both supposed the same Way. But if the Latitude had been North, and the Declination South, then

	Ho.	Min.	Sec.
From	6	0	0
Take the Time last found	1	5	56
And you will have the Time when the Sun is upon the Prime Vertical Circle below the Horizon in the Morning.	4	54	04

Or,

the Square 27. Now compare this last Num-
ber with the 609 of the Declination
counted upon the Index and you will have on
the Arch the Quantity of Time from
the Hour of 2. and the Sun is }
Add the Time last found 7. 5 56
Half and Well Done.

Their Sum is the Time when the Sun is }
due West below the Horizon. 7 5 56

PROBLEM V.

*The Latitude and Declination given. to find the
Sun's Amplitude.*

Find the Cosine of the Latitude and Sine of
the Declination by Problem I.

EXAMPLE.

The Latitude 52. 30 N, its Cosine 609.
Declination 20. 00 N, its Sine 342.

Set 342 the Sine of the Declination counted
upon the Square, to 609 the Sine of the Lati-
tude counted upon the Index, and you will
have upon the Arch 34°. 00', the Sun's Am-
plitude required, which is always the same
Way with the Declination, that is, Northerly
when the Declination is Northerly, and South-
erly if the Declination be Southerly.

PROBLEM VI.

PROBLEM VI.

The Latitude and Sun's Declination given, to find his Altitude or Depression at the Hour of Six.

Latitude 52. 30 N, its Sine 793.

Declination 20. 00 N.

Set the Index to 20. 00 upon the Arch, the Sun's Declination, and slide the Square to 793 the Sine of the Latitude counted upon the Index, and it will cut on the Square 271, which is the Sine of the Altitude at Six, and must be applied to 100 upon the Index to find its corresponding Arch, which is 15°. 44 the Sun's Altitude required.

N. B. When the Sun has the same Declination South, his Depression at the Hour of Six will be the same as above.

PROBLEM VII.

The Latitude and Sun's Altitude at Six given, to find his Azimuth at the Hour of Six.

Latitude — 52. 30 — its Sine 793

Sun's Altitude at Six 15. 44 — its Sine 271

Slide the Index and Square until 793, the Sine of the Latitude counted on the Index intersect 271, the Sine of the Latitude at Six

R

counted

counted upon the Square, and let the Index remain while you slide the Square to 609 the Cosine of the Latitude counted upon the Index, and you will have 208 upon the Square. Now compare this Number with 963 the Cosine of the Altitude counted upon the Index, and you will have on the Arch $12^{\circ}.30$ the Azimuth of the Sun from the East or West Points at the Hour of Six, as was required.

P R O B L E M VIII.

The Latitude and Sun's Declination given, to find the Sun's Ascensional Difference.

First find the Sine and Cosine of the Latitude and Declination by the 5th Problem.

EXAMPLE.

The Latitude 51.30 — *Sine* 782 — *Cosine* 622
Declination 19.38 — 336 — 942

Set the Sine of the Sun's Declination 336 counted on the Square, to 622 the Cosine of the Latitude counted upon the Index, where let the Index stay, and slide the Square to 783 the Sine of the Latitude counted upon the Index, which will cut on the Index 422; set this Number to 942 the Cosine of the Declination counted on the Index. and on the Arch you will have $26^{\circ}.39'$ for the Ascensional Difference,

ference, which being converted into Hours and Minutes, by allowing 15 Degrees to an Hour, and 15 Minutes to one Minute of Time, will give 1 Hour, 46 Minutes. 36 Seconds.

If the Latitude and Declination are both the same Way.

<i>For the Sun's Rising.</i>			
	<i>Ho.</i>	<i>Min.</i>	<i>Sec.</i>
<i>From</i>	6	00	00
<i>Take the Ascensional Difference</i>	1	46	36
<i>Remains the Time of Sun-Rising</i>	4	13	24

<i>For the Sun's Setting.</i>			
	<i>Ho.</i>	<i>Min.</i>	<i>Sec.</i>
<i>To</i>	6	00	00
<i>Add the Ascensional Difference</i>	1	46	36
<i>Remains the Time of Sun-Setting</i>	7	46	36

If the Sun's Declination and Latitude are One North and the other South, then add the Ascensional Difference to 6 Hours for Sun-rising, and subtract it for Sun-setting.

Because the Time of the Sun-setting is the Space of Time between Noon and the End of the Day; consequently it is the half Length of the Day: therefore, if the Hour of Sun-setting be doubled, you have the Length of the Day, or Time the Sun is above the Horizon, which, in this Example, is 15 Ho. 33'. 12".

And, because the Hour of Sun-rising is the Space of Time between Midnight and Sun-rising, and therefore is half the Length of the Night, its Double will be the Length of the Night 8 Ho. 26'. 48".

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Hence

Hence it appears, that when the Sun's Declination is the same, the *Amplitudes, Ascensional Differences, Time of the Sun's Rising and Setting, the Length of the Days and Nights* are also the same.

It is likewise observable, that when the Declination is the same South, the Sun's Rising is the same Hour of his Setting; and Sun-setting the same Hour of his rising, as when he was North; and the Length of the Day when the same Declination is North, is the Length of the Day in the same South Declination; and the Length of the Night in North Declination is the Length of the Day in South Declination, and the contrary.

PROBLEM IX.

The Latitude, Sun's Declination and Altitude given, to find the Sun's Azimuth.

Find the Sines and Cosines as before, by Problem I.

EXAMPLE I.

Latitude	51. 30 N.	Sine 782	Cosine 672
Declination	19. 38 N.	336	942
Altitude	38. 18	619	784
Alt. on Prime Vert.	25. 27	429	

As the Sun's Declination is North, find his Height in the Prime Vertical for the Day proposed,

posed by Problem III. which will be as follows.

Slide the Square and Index until the Sine of the Latitude 782, counted upon the Index, intersect 336, the Sine of the Declination counted upon the Square, and you will have on the Arch the Sun's Altitude on the Prime Vertical for that Day $25^{\circ}. 27'$, find the Sine, &c. of this Altitude as before, and take the Difference between 429 the Sine of the Sun's Altitude on the Prime Vertical, and 619 the Sine of the present Altitude, which is 190.

Now slide the Square and Index till this Number 190 counted on the Square intersect 622 the Cosine of the Latitude counted upon the Index, there let the Index remain, and slide the Square to 782 the Sine of the Latitude counted upon the Index, which will cut on the Square 242; then slide this Number to 784 the Cosine of the present Altitude, counted also on the Index, and you will have on the Limb $17^{\circ}. 46'$ the Azimuth from the East or West either Northward or Southward.

To determine which Way the Azimuth is. If the observed Altitude is greater than the Altitude on the Prime Vertical, it is towards the South.

And if the observed Altitude is less than the Altitude on the Prime Vertical, the Azimuth is towards the North. But if the given Altitude,

tude, and Altitude on the Vertical is equal, he is directly in the East and West.

The Reader will observe, that in this Example the observed Altitude was greater than the Altitude on the Prime Vertical; therefore, the Azimuth found by this Instrument was Southward of the East and West Points $17^{\circ}.46'$, which, added to $90^{\circ}.00'$, makes $107^{\circ}.46'$, the Azimuth from the North, and subtracted from 90° , leaves $72^{\circ}.14'$, the Azimuth from the South.

But the contrary will happen when the observed Altitude is less than the Altitude on the Prime Vertical.

If the Declination be South, and the Latitude North, or contrary, by Problem V. find the Sun's Amplitude for the Day proposed.

EXAMPLE II.

Latitude	52. 30 N	Sine 793	Cofine 609
Declination	11. 30 S	— 119	—
Altitude	13. 20	— 230	— 974
Amplitude	19. 07	— 327	—

To find the Amplitude by Problem V.

Count 199 the Sine of the Sun's Declination upon the Square, to which bring 609 the Cofine of the Latitude counted upon the Index, and you will have on the Arch the Sun's Amplitude required $19^{\circ}.07'$.

Set

Set 230 the Sine of the Sun's Altitude counted on the Square, to 609 the Cosine of the Latitude counted on the Index; letting the Index remain in this Position, slide the Square to 793 the Sine of the Latitude, which will cut on the Square 299, add this Number to the Sine of the Amplitude 327, which makes 626, to which, counted upon the Square, bring 974 the Cosine of the Sun's Altitude counted upon the Index, and you will have $40^{\circ}. 11'$ upon the Arch for the Sun's Azimuth required, from the East or West Points Southwards.

PROBLEM X.

The Latitude, Sun's Declination, and Altitude given, to find the Hour of the Day.

If the Latitude and Declination are both the same Way, find the Sun's Altitude at Six, by Problem VI. and the Sines and Cosines by Problem V.

EXAMPLE I.

Latitude	51. 30	— Sine 793	— Cosine 609
Declination	11. 15	— 195	— 980
Altitude Obs.	42. 33	— 676	—
Altitude at 6,	9. 05	— 158	—

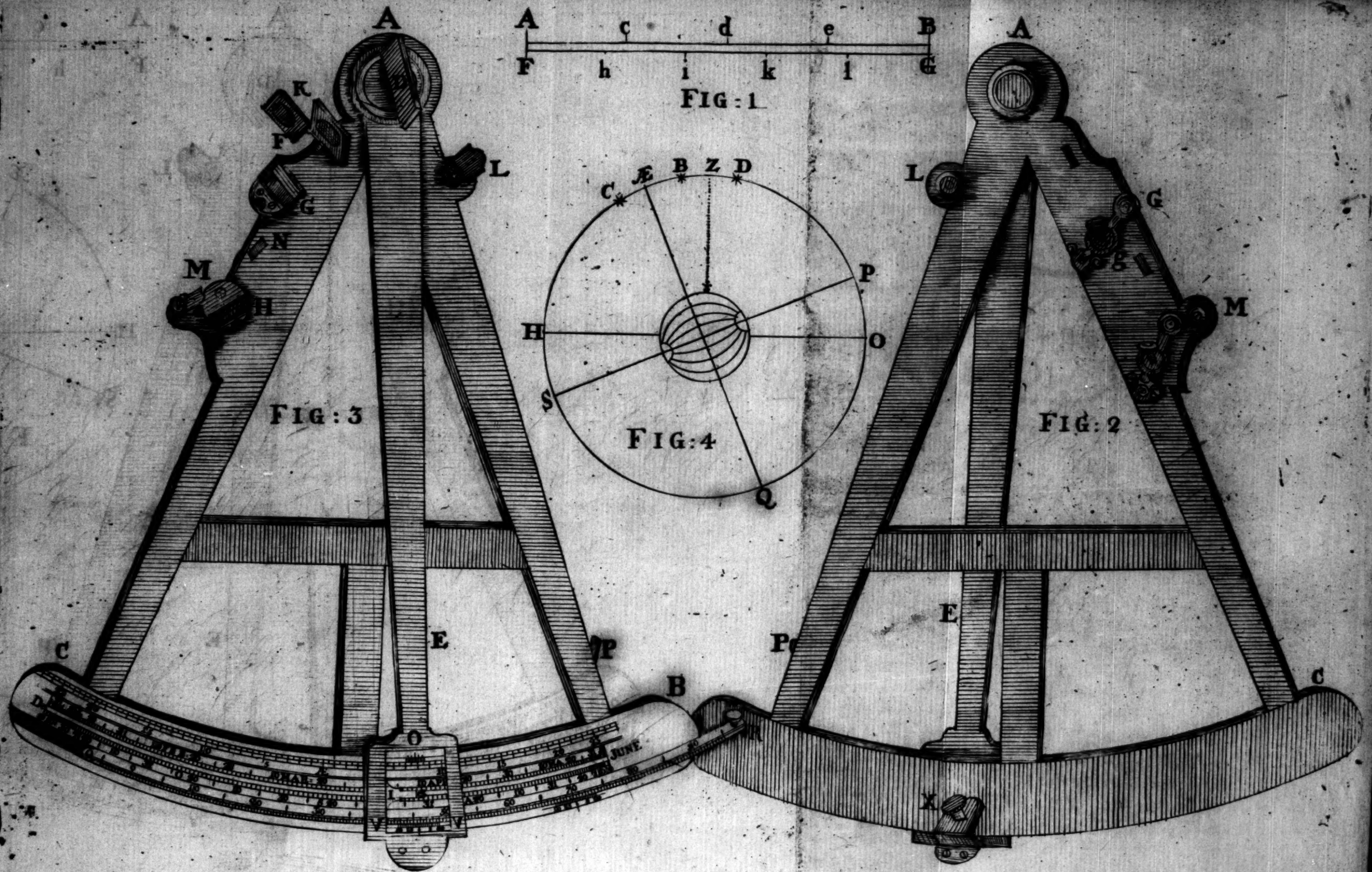
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The Difference between the Sine of the Altitude at Six 158, and 676 the Sine of the given Altitude, will be 518, to which, counted upon the Side, set the Square, and move the Index until the Square cut 609 the Cosine of the Latitude, where let the Index remain, and slide the Square to 100 upon the Index, and it will cut upon the Side 852; hold the Square fast at this Point, and move the Index until 980 the Sine, Compliment of the Declination counted thereon, intersect the Square, and it will give upon the Arch $60^{\circ} 15'$ which, converted into Time, is four Hours one Minute from six o'Clock.

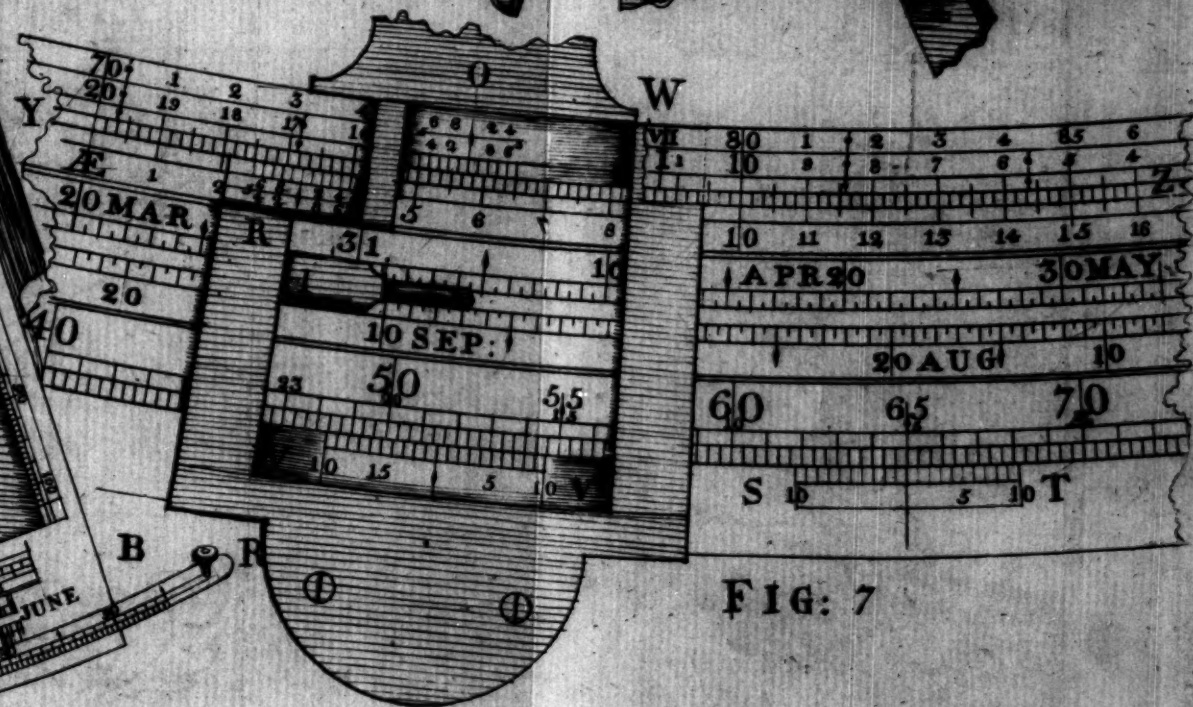
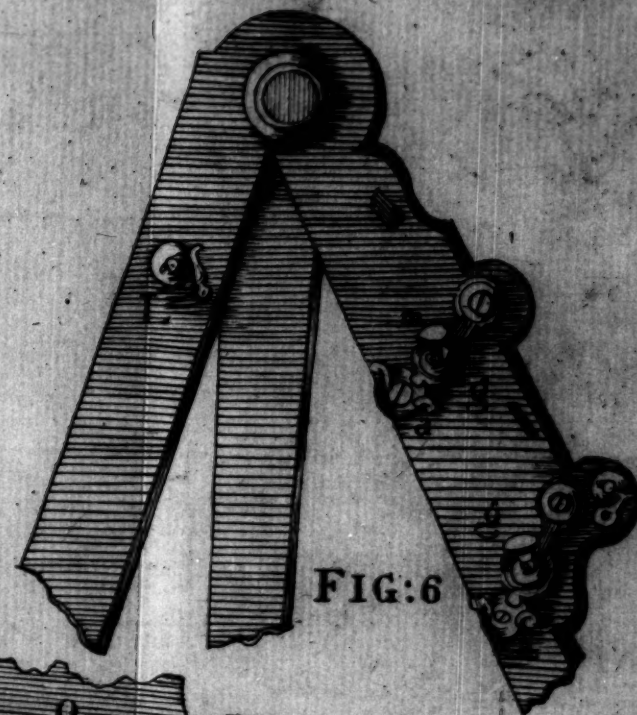
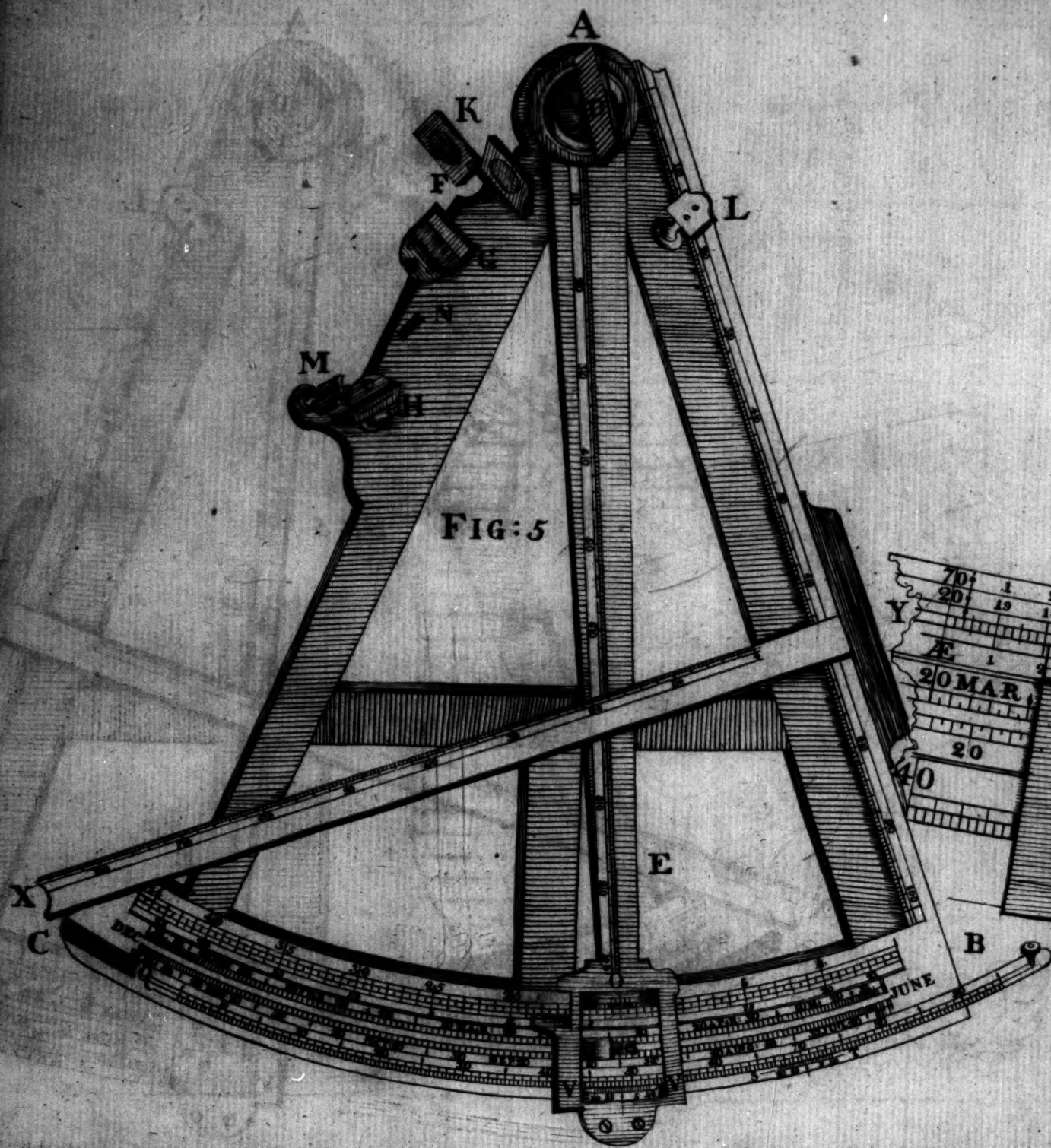
N. B. If the given Altitude be greater than the Altitude at Six, the Time found is to the Southward of Six; but if it be less, the Time found will be to the Northward of Six.

EXAMPLE II.

If the Sun's Declination and Latitude be on contrary Sides, that is, one North and the other South, find his Depression at the Hour of Six by Problem V. for the Day proposed, which will be equal to the Height at Six, if the Declination be the same, though one be North, and the other South.



Geo: Adams Jan: 24 1754.



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